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Results from the ENVIMAT-model

Ari Nissinen and Hannu Savolainen (eds.)

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The Centre for Sustainable Consumption and Production

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ABSTRACT

Carbon footprint and raw material requirement of public procurement and household consumption in Finland – Results from the ENVIMAT-model

The aim of the research was to analyse the carbon footprint (i.e. life-cycle greenhouse gas emissions) and raw material requirements (RMR) for public procurement and household consumption. The main method used was the environmentally extended input-output model ENVIMAT, supplemented with statistics on public procurement.

Greenhouse gas emissions for the final domestic demand, i.e. the consumption-based emissions of Finland, amounted to 73.4 million tons carbon dioxide equivalents (Mt CO_2e) in 2015. This can also be seen as the carbon footprint of Finland, and it was 33 % bigger than the territorial emissions which form the basis of the official national inventories.

The carbon footprint for public procurement in 2015 was 8.3 Mt CO_2e. State procurement accounted for 1.78 Mt, municipalities for 4.73 Mt CO_2e, and federations of municipalities (FM) for 1.79 Mt CO_2e. The carbon footprint of investments made by public organisations amounted to 2.7 Mt CO_2e. In state procurement 42 % of the emissions were caused by buying services, 38 % from goods, 12 % from rents, and 8 % were due to other costs. Buying goods caused the largest emission share in the defence administration (55 %), whereas services caused the largest share (81 %) in the traffic and communications sector. In the procurement made by municipalities and federations of municipalities 42–43 % of emissions were caused by the procurement of services and 52 % from goods. Looking at state administration, defence caused the largest share (43 %) of emissions, and next were the traffic and communications (21 %) and the ministry of the interior (10 %). Urban municipalities caused 3.33 Mt of emissions, and semi-urban municipalities caused 0.69 Mt and rural municipalities 0.71 Mt. Hospital districts had the largest emissions (1.03 Mt) among the federations of municipalities.

The raw material requirement of public procurement amounted to 19.5 Mt in 2015. The share of state procurement was 34 %, whereas municipalities and FM caused the remaining 66 %. The RMR of investments made by public organisations amounted to 25.7 Mt. The RMR of household consumption in 2015 was 64.8 Mt. The share of other products and services came to 32 %, housing including energy use amounted to 30 %, foodstuffs and non-alcoholic beverages contributed 26 % and transport 12 %.

Regarding the carbon footprint of households in 2016, transport caused 30 % of all carbon emission equivalents, housing and energy use 29 %, foodstuffs and non-alcoholic beverages 19 %, and other products and services 22 %. The overall carbon footprint was 53.4 Mt CO_2e in 2000 and 60.1 Mt in 2016 (12.5 % growth). Emissions were the largest in 2007 (66.6 Mt). A structural decomposition of the change in the carbon footprint from 2000 to 2016 shows three major factors: change in consumption expenditure (which alone would change the footprint by +30.7 %), change in consumption structure (-5.7 %) and technological change (-12.5 %). The annual average carbon footprint per capita varied between 10.1 and 12.6 tons of CO_2e.

Statistics Finland's Household Budget Survey was used to analyse different households. In the lowest income decile the carbon footprint was 7.2 t CO_2e per consumption unit, and in the highest income decile it was 19.0. The emission intensity (i.e. emissions per euro consumed) did not have any clear relationship to the income. Regarding types of households, couples without children and couples with children had the largest footprint per consumption unit. When housing was not taken into account, households in inner urban areas had the smallest and households in peri-urban and rural areas close to urban areas had the largest carbon footprint per consumption unit. Of the consumption sectors, transport had the highest emission intensity (0.81 kg CO2e /€). Additionally, food had a high emission intensity (0.76). The two expenditure categories related to housing had smaller intensities (0.51 and 0.45), and other goods and services had the smallest (0.24). The average emission intensity was around 0.5.

Keywords: economy, public procurement, consumption, material flows, input-output analysis, greenhouse gas emissions, carbon footprint

TIIVISTELMÄ

Julkisten hankintojen ja kotitalouksien kulutuksen hiilijalanjälki ja luonnonvarojen käyttö – ENVIMAT-mallinnuksen tuloksia

Tutkimuksessa analysoitiin julkisten hankintojen ja kotitalouksien kulutuksen elinkaarisia kasvihuonekaasupäästöjä ja raaka-aineiden käyttöä. Menetelmänä käytettiin ympäristölaajennettua panos-tuotosmallia ENVIMAT, jota täydennettiin julkisten hankintojen tilastoilla.

Kulutusperusteisesti lasketut kotimaan loppukäytön kasvihuonekaasupäästöt olivat 73,4 miljoonaa tonnia hiilidioksidiekvivalenttia (Mt CO_2e) vuonna 2015. Tämä niin kutsuttu Suomen hiilijalanjälki oli 33 % suurempi kuin Suomen alueella syntynyt virallisissa tilastoissa esitettävä päästö.

Julkisten hankintojen hiilijalanjälki vuonna 2015 oli 8,3 Mt CO_2e. Siitä 1,78 Mt aiheutui valtion, 4,73 Mt kuntien ja 1,79 Mt kuntayhtymien hankinnoista. Julkisten organisaatioiden tekemien investointien hiilijalanjälki oli 2,7 Mt CO_2e. Valtion hankinnoissa 42 % päästöistä aiheutui palvelujen ostoista, 38 % aineista, tarvikkeista ja tavaroista, 12 % vuokrista ja 8 % muista kuluista. Aineet, tarvikkeet ja tavarat aiheuttivat hallinnonalojen päästöistä suurimman osuuden puolustusministeriön alalla (55 %), ja palvelujen osuus oli suurin (81 %) liikenne- ja viestintäministeriön hallinnonalalla. Kuntien ja kuntayhtymien hankinnoissa 42–43 % aiheutui palvelujen ostoista ja 52 % aineista, tarvikkeista ja tavaroista.

Valtion hallinnonaloista eniten kasvihuonekaasupäästöjä (43 %) aiheutti puolustusministeriön hallinnonala, ja seuraavaksi suurimmat olivat liikenne- ja viestintäministeriön (21 %) ja sisäministeriön (10 %) hallinnonalat. Kuntien hankintojen päästöistä 3,33 Mt tuli kaupunkimaisista, 0,69 Mt taajaan asutuista ja 0,71 Mt maaseutumaisista kunnista. Kuntayhtymien suurin päästö (1,03 Mt) aiheutui sairaanhoitopiireistä.

Julkisten hankintojen aiheuttama raaka-ainekäyttö vuonna 2015 oli 19,5 Mt. Valtion osuus oli 34 %, kun kuntien ja kuntayhtymien yhteenlaskettu osuus oli 66 %. Julkisten organisaatioiden tekemien investointien raaka-ainekäyttö oli 25,7 Mt. Kotitalouksien kulutuksesta aiheutuva raaka-aineiden käyttö vuonna 2015 oli 64,8 Mt. Tästä muiden tavaroiden ja palvelujen osuus oli 32 %, asumisen ja energian 30 %, elintarvikkeiden ja alkoholittomien juomien 26 % ja liikkumisen osuus 12 %.

Kotitalouksien kulutuksen hiilijalanjäljestä vuonna 2016 liikkuminen muodosti 30 %, asuminen ja siihen liittyvä energian käyttö 29 %, elintarvikkeet ja alkoholittomat juomat 19 %, ja muut tavarat ja palvelut 22 %. Hiilijalanjälki oli 53,4 Mt CO_2e vuonna 2000 ja 60,1 Mt vuonna 2016 (12,5 % kasvu). Suurimmillaan päästöt olivat 66,6 Mt vuonna 2007. Hiilijalanjäljen muutos 2000–2016 voidaan osittaa kolmelle tekijälle: kulutusmenojen muutokselle (joka olisi yksinään muuttanut päästöä +30,7 %), kulutusrakenteen muutokselle (-5,7 %) ja teknologiselle muutokselle (-12,5 %). Keskimääräinen vuotuinen hiilijalanjälki henkilöä kohden vaihteli 10,1 tonnista 12,6 tonniin CO_2e.

Tilastokeskuksen kulutustutkimusaineiston avulla voidaan tarkastella erilaisia kotitalouksia. Alimmassa tulodesiilissä hiilijalanjälki oli 7,2 t CO_2e kulutusyksikköä kohti, ja korkeimmassa tulodesiilissä 19,0. Päästöintensiteetillä eli päästöllä kulutettua euroa kohti ei ollut selvää riippuvuutta tuloista. Kotitaloustyypeistä lapsettomilla pareilla ja kahden huoltajan lapsiperheillä oli suurimmat päästöt kulutusyksikköä kohti. Kun asumista ei lasketa mukaan, niin hiilijalanjälki kulutusyksikköä kohti on pienin sisemmillä kaupunkialueilla ja suurin kaupunkien kehysalueilla ja kaupunkien läheisellä maaseudulla. Korkein päästöintensiteetti oli liikenteellä, 0,81 kg CO_2e/€. Myös ruoalla oli korkea (0,76) päästöintensiteetti. Asumisen kahdella menoluokalla oli edellisiä selkeästi pienemmät päästöintensiteetit (0,51 ja 0,45), ja pienin hiilijalanjälki kulutettua euroa kohden oli muilla tavaroilla ja palveluilla (0,24). Keskimääräinen päästöintensiteetti oli noin 0,5.

Asiasanat: kansantalous, julkiset hankinnat, kulutus, materiaalivirrat, panos-tuotosanalyysi, kasvihuonekaasupäästöt, hiilijalanjälki

SAMMANDRAG

Koldioxidavtryck och råvaruanvändning i offentliga upphandlingar och i hushållens konsumtion

– Resultat av analys med modellen ENVIMAT

I studien analyserades växthusgasutsläppen och råvaruanvändningen i offentliga upphandlingar och i hushållens konsumtion livscykelmässigt. Som metod användes den miljöanpassade input-output-modellen ENVIMAT, som kompletterades med statistik om offentliga upphandlingar.

Växthusgasutsläppen från den inhemska slutanvändningen, uträknade på konsumtionsbasis, var 73,4 miljoner ton koldioxidekvivalenter (Mt CO_2e) 2015. Det här så kallade finländska koldioxidavtrycket var 33 procent större än det utsläpp inom Finland som presenteras i officiell statistik.

Koldioxidavtrycket hos de offentliga upphandlingarna var 8,3 Mt CO_2e 2015. Av det kom 1,78 Mt från statens, 4,73 Mt från kommunernas och 1,79 Mt från samkommunernas upphandlingar. Koldioxidavtrycket hos de offentliga organisationernas investeringar var 2,7 Mt CO_2e. I statens upphandlingar härrörde 42 procent av utsläppen från köp av service, 38 procent från material, förnödenheter och varor, 12 procent från hyror och 8 procent från andra kostnader. Av förvaltningsområdenas utsläpp utgjorde material, förnödenheter och varor största andelen inom försvarsministeriets område (55 %), och service den största (81 %) inom kommunikationsministeriets. I kommunernas och samkommunernas upphandlingar kom 42–43 procent av utsläppen från köp av service och 52 procent från material, förnödenheter och varor.

Mest växthusgasutsläpp (43 %) åstadkoms av försvarsministeriets förvaltningsområde, därefter av kommunikationsministeriets (21 %) och inrikesministeriets (10 %) förvaltningsområden. Av kommunernas utsläpp kom 3,33 Mt från urbana, 0,69 Mt från tätt bebyggda och 0,71 Mt från landsortsmässiga kommuner. Samkommunernas största utsläpp (1,03 Mt) orsakades av sjukvårdsdistrikten.

Råvaruanvändningen orsakad av offentliga upphandlingar var 19,5 Mt år 2015. Statens andel av råvaruanvändningen var 34 procent, medan kommunernas och samkommunernas sammanlagda andel var 66 procent. Råvaruanvändningen i de offentliga organisationernas investeringar var 25,7 Mt. Hushållens konsumtion stod för en råvaruanvändning på 64,8 Mt år 2015. Av denna stod övriga varor och tjänster för 32 procent, boende och energi för 30 procent, livsmedel och alkoholfria drycker för 26 procent och transporter för 12 procent.

I koldioxidavtrycket från hushållens konsumtion 2016 stod transporter för 30 procent, boende och energianvändning för 29 procent, livsmedel och alkoholfria drycker för 19 procent och övriga varor och tjänster för 22 procent. Koldioxidavtrycket var 53,4 Mt CO_2e år 2000 och 60,1 Mt år 2016 (en ökning på 12,5 %). Som störst var utsläppen 66,6 Mt år 2007. Förändringen i koldioxidavtryck 2000–2016 kan fördelas på tre faktorer: en ändring i konsumtionskostnaderna (enbart dessa hade ändrat utsläppen +30,7 %), en ändring i konsumtionsstrukturen (-5,7 %) och en teknisk förändring (-12,5 %). Det genomsnittliga årliga koldioxidavtrycket per person varierade mellan 10,1 ton och 12,6 ton CO_2e.

Med hjälp av Statistikcentralens konsumtionsundersökningsmaterial kan man följa olika slags hushåll. I den lägsta inkomstdecilen var koldioxidavtrycket 7,2 t CO_2e per konsumtionsenhet, och i den högsta 19,0. Det förekom inget klart samband mellan utsläppsintensiteten, dvs. utsläpp per förbrukad euro, och inkomsten. Av hushållstyperna hade barnlösa par och barnfamiljer med två vårdnadshavare de största utsläppen per konsumtionsenhet. När boendet inte räknas med är koldioxidavtrycket per konsumtionsenhet minst i de inre stadsområdena och störst i städernas kransområden och på landsbygden nära städer. Den högsta utsläppsintensiteten förekom i trafiken, 0,81 kg CO2e /€. Maten hade också en hög (0,76) utsläppsintensitet. De två boendeutgiftsklasserna hade klart mindre utsläppsintensitet (0,51 och 0,45), än de ovan nämnda, och det minsta koldioxidavtrycket per förbrukad euro hade övriga varor och tjänster (0,24). Den genomsnittliga utsläppsintensiteten var ca 0,5.

Nyckelord: Samhällsekonomi, offentliga upphandlingar, konsumtion, materialströmmar, input-output-analys, växthusgasutsläpp, koldioxidavtryck

FOREWORD

Our information on the environmental impacts of consumption changed with the ENVIMAT study published in 2009 as well as the Eco-Benchmark study and the European EIPRO study, published some years earlier. While unnecessary belongings and waste were found to be the main worrying consumption topics before, these studies also examined housing, food, transportation and services. As they say in Sweden, 'bilen, biffen, bostaden' (the car, the steak and the house).

We decided to update the analysis for the ENVIMAT project, published ten years ago, specifically in terms of consumption, but also including a brief survey of the results of the entire national economy. The effects of consumption on the climate have also been of great interest after the Intergovernmental Panel on Climate Change (IPCC) published its 1.5° report. The new results provide information on how the effects of consumption on the climate have changed over a period of ten years. The previous results also served several other study groups and projects, and the updated results are required for numerous applications.

In the project, the analysis on public procurement has a particular novelty value. First of all, results successfully describing the public sector have not been previously obtained by using the method of input and output, and the method developed in the project is a new one, even on an international level. Secondly, great attention is constantly paid to public procurement, since it is considered as an important factor resulting in a demand for more sustainable goods and services.

The timing was also affected by the fact that two key researchers in the field of consumption are about to retire, and a considerable amount of know-how and knowledge will cease to be available in the research sphere. These researchers are Professor Ilmo Mäenpää from the Thule Institute at the University of Oulu and SYKE, and Project Manager, Adjunct Professor Juha Nurmela from Statistics Finland. Ilmo Mäenpää has been in charge of the environmentally extended analysis of the input and outputs of the national economy for decades, and Juha Nurmela has been in charge of the Statistics Finland consumption research, based on extensive surveys. We had the good fortune of including them in this one last project.

The Ministry of the Environment funding for the so-called KUHIMA project launched the analysis for public procurement and household consumption, but in the course of the work, connections to other projects became apparent, and the points of view of the study could be extended by means of cooperation between projects. The comprehensive analysis on the environmental effects of the national economy has been prepared in cooperation with the 'Transition Pathways Towards Circular Economy' (TRANSCIRC) project funded by the Academy of Finland. In addition, analyses on household consumption have been prepared in conjunction with the 'Beyond MALPE-coordination: integrative envisioning' (BeMInE), which has received funding from the Strategic Research Council at the Academy of Finland. We also thank Statistics Finland for cooperation in using the materials of the Consumption study.

We give warm thanks to the entire researcher consortium of Ari Nissinen, Hannu Savolainen, Marja Salo, Katriina Alhola, Ilmo Mäenpää and Juha Nurmela for the crucial analysis, and to Roosa Komokallio and Pirjo Lehtovaara for their assistance in the layout of the report.

Taina Nikula

Ministerial Adviser, Ministry of the Environment

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1 Introduction - Climate change mitigation requires a better knowledge base on public and private consumption

Nissinen Ari

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Consumption has attracted attention in both the climate and energy strategy, the Medium-term Climate Change Policy Plan (KAISU) and in the Government's report on the future. People's consumer choices and lifestyles became a topic for discussion particularly in autumn 2018, when the 1.5° report of the Intergovernmental Panel on Climate Change emphasised the urgency of climate measures. The objectives for reducing greenhouse gas emissions for 2020, 2030 and 2050 are so challenging that they cannot be met without great changes in private and public consumption. At the same time, an extensive attempt is also made to improve resource efficiency.

It is often said that 70% of greenhouse gas emissions are the result of consumption. This may be misleading if we are not also told that these are conditions calculated based on consumption. It may be surprising that energy production and other types of industry do not account for a larger percentage of the emissions. They do cause the majority of the region-based emissions in Finland, on which the official greenhouse gas emissions value of Finland is based. The 70% mentioned in discussions (which is actually more specifically 68%) is based on the ENVIMAT study published in 2009 (Seppälä et al. 2009, pp. 86–87). In addition to an examination based on region, an examination of the end-use within the country was also made, and in this examination, the percentage of households was 68% of greenhouse gas emissions. The end-use within the country or the examination emphasising consumption (Nissinen et al. 2015, Salo et al. 2016) only takes into account the environmental effects of the life cycle of goods and services used in Finland and investments made in Finland, which means that exports are deduced from the amount of products produced in Finland, and imports are added to it. The end-use within the country only includes household consumption, public consumption and investments made in Finland. The emissions from the manufacturing processes of goods and energy production are taken into account when the life cycle emissions of the products consumed are allocated to end-use within the country. Since the published results of the ENVIMAT study apply to the situation in 2005 or over a decade ago, new information is required on the distribution of emissions and the use of natural resources in the national economy.

The 2013 government resolution 'From less, more wisely: Revised program for sustainable consumption and production' included steering methods for both private and public consumption, and Finland is still at the top in the programme work for sustainable consumption and production. However, in the background of the steering methods, information is required on the development of emissions and material consumption, and on the most important fields of public and private consumption which may be affected by means of steering. Public procurement is considered to lead the way towards sustainable consumption with good examples and to create demand for climate-friendly solutions.However, a new method was required to determine the carbon footprint of public procurement and the use of raw materials on the level of the entire national economy, since the calculations could not be previously made at a sufficient level of accuracy. The ENVIMAT study (Seppälä et al. 2009), published in 2009, presented the environmental effects of the life cycle of production and consumption in Finland by industries, by groups of products and by consumption sectors for 2002 and 2005, but at the time, the method did not yet contain a breakdown on the significance of the environmental effects of public procurement.

The objective of this study was to analyse the carbon footprint of public procurement, household consumption (i.e. the greenhouse gas emissions of their life cycle) and the use of raw materials. In addition, the objective was to develop the environmentally extended input and output model by supplementing the ENVIMAT model with public procurement statistics and the related calculations, so that the greenhouse gases of the life cycle of public procurement, as well as the use of raw materials and natural resources, may be determined.

2 Material and methods for the ENVIMAT study

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2.1 ENVIMAT – The environmentally extended input-output model for the national economy of Finland

Monetary model

The ENVIMAT model is the environmentally extended input-output model for the national economy of Finland (Figure 1, see a more detailed description of the basic structure of the model: Seppälä et al. 2009). In the model, the production activities have been divided into 148 industries and 229 products.

In the model, the production structure of the economy is systematically described in tables depicting products, industries and their supply and use (MIOT). The supply table indicates which products and how much each Finnish industry has produced during the year. As a technical detail, it should be mentioned that product-specific data are indicated in the rows, and industry data are indicated in columns. In addition to the industries, imports have been indicated in the last column of the supply table.

The first column of the use table indicates the intermediate use in various industries. After this, the final use of products for the consumption expenditure of households, non-profit institutions serving the households and general government, for gross capital formation, for changes in inventory and exports is presented. The taxes less subsidies on products as well as the added value included in the intermediate use are indicated below the products. Domestic products and imported products are initially indicated in the same use table. Later, they are separated to create a use table for domestic products and a use table for imported products.

The supply and use tables should correspond to each other in terms of certain characteristics (so-called identities). Thus, the sums on the lines for supply table products shall be equivalent to the sums on the lines for use table products. In a similar way, the sums in the columns for domestic industries shall be identical in both the supply and use tables.

The input-output model is derived from the supply and use tables as follows. A market share matrix is formed based on the supply table. It indicates the percentage of each industry in the domestic production of various products. The coefficient matrix is formed based on the industry columns in the use table for domestic products by dividing the use of products by the outputs of the industry. When the market share matrix is used to multiply the coefficient matrix, the coefficient matrix for the industry * industry - intermediate use is derived. The coefficient matrix for intermediate use indicates the extent to which the production of other domestic industries is directly used for the production of each industry. The coefficient matrix for intermediate use is further used to create the so-called Leontief inverse matrix (see e.g. Miller & Blair 2009). Each column in the inverse matrix indicates the extent to which the industry corresponding to the column has directly or indirectly used products from each of the other domestic industries. It may also be interpreted that the columns in the Leontief inverse matrix indicate the extent to which production from other industries have been used in total for the production of a product unit for each industry, directly or indirectly.

However, the Leontief inverse matrix only includes the flows of domestic products. The life cycle usage of imported products may be added simply by dividing the import matrix by the outputs of the industries, which will result in the coefficient matrix for imports. The desired life cycle use matrix for imports will be obtained by multiplying the Leontief inverse matrix by the coefficient matrix for imports.

The ENVIMAT model was now estimated based on the 2015 data. The previous version was made based on the 2010 data. The 2010 supply and use table data was received from Statistics Finland. When moving on to the 2015 estimate, the Statistics Finland data security requirements had been updated so that only output data for the industries, intermediate use data in the form of sums only, and also the output data for the primary production industries by product were received at the level of accuracy required for the ENVIMAT model. In addition, slightly more detailed data on the consumption expenditure of households and general government and capital formation may be derived from the national accounts (Statistics Finland 2017a). Based on the Customs Agency international trade statistics, the exports and imports of goods, and based on the national accounts, the export and import of services may be estimated by product.

Since not all data is accurate, the figures will have to be estimated, and at the same time, the equivalence of the supply and use tables will be implemented. The supply and use tables for a total of 148 industries and 229 products were estimated based on the 2010 tables. Initially, the cells with available specialised data were estimated, and the so-called RAS method (Miller & Blair 2009) was applied to the rest of the cells. In the method, the rows and columns of the tables are modified gradually so that the sums in the table columns and rows are equal in the end.

In the use table, household consumption expenditure have been divided according to a product classification based on the industries. When the consumption expenditure is examined separately, a purposeful commodity classification (COICOP, Statistics Finland 2017b) is usually used. A conversion table has been created in the ENVIMAT model. In the table, products for each industry are classified to the COICOP classification of 62 different consumer commodities. In the conversion table, the shares of trade and transportation are added to the purchasing price of consumer commodities in addition to the product taxes and subsidies.

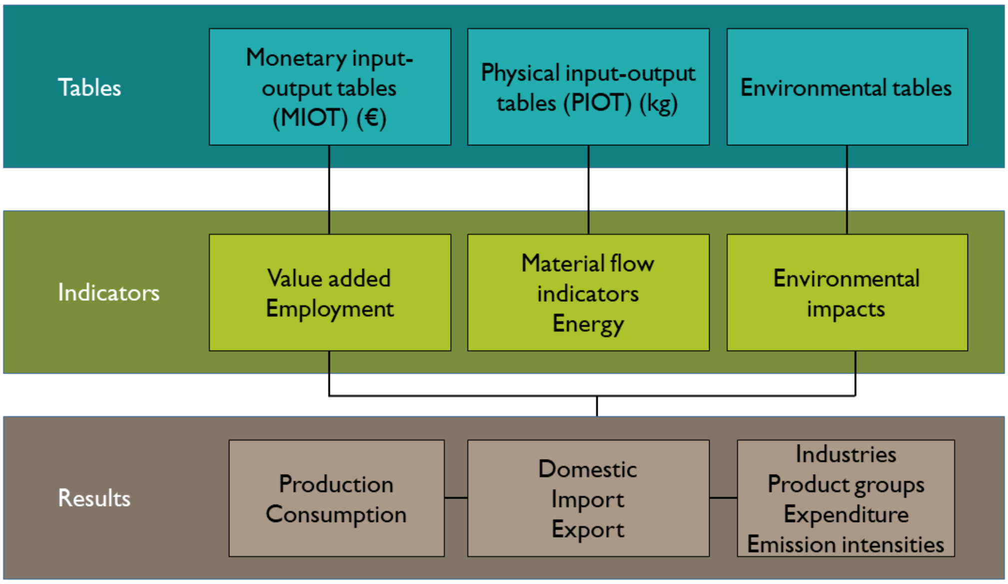

Figure 1. Structure and sources of the ENVIMAT model: tables, indicators and uses for analytic purposes.

Environmental extensions of the model

The 2015 ENVIMAT model includes the following environmental extensions:

- The use of raw materials (PIOT, used and unused extraction of the following types of materials: crops, wild plants and animals, raw wood, fossil fuels, metal ore, industrial minerals, construction minerals, soil material)

- Greenhouse gas emissions (CO_2 of biological origin, CO_2 fossil, CH_4, N_2O and F gases.)
- Air pollution (SO_2, NO_x, NH_3, NMVOC, PM2,5 and PM10).

The use of raw materials has been measured in accordance with the Eurostat definitions and measuring methods (Eurostat 2017). The sources of domestic data include the crop statistics for crops from the Natural Resources Institute Finland, forest statistics and fishery statistics (Natural Resources Institute Finland 2017), the mining statistics from the Geological Survey of Finland (Geological Survey of Finland 2017) and the soil material statistics from the European Aggregates Association (European Aggregates Association 2017). The sources and methods have been described in more detail in reports by Mäenpää et al. (2017a, 2017b) and Seppälä et al. (2009).

The life cycle use data for the raw material of imported products are based on the data from the international LCI data bank (Ecoinvent 2017). In terms of missing product information, the data bank has been completed with other available, product-specific LC inventory data.

The majority of both greenhouse and air pollution emissions are created in connection with energy production and consumption. This is why the 2015 consumption of 61 types of energy by industry was estimated using the Statistics Finland Energy accounting (Statistics Finland 2017c), Energy Statistics (Statistics Finland 2017d) and the Finnish Environment Institute VAHTI database (Finnish Environment Institute 2018). Energy-based emissions were estimated by assuming that the emission coefficients for each type of energy are the same regardless of how the energy is used. The detailed nature of the energy type classification promotes the sufficient accuracy of the assumption.

For greenhouse gas emissions specific to certain energy types, the carbon dioxide emissions were derived from the 2015 fuel classification published by Statistics Finland (Statistics Finland 2017e). The fuel-specific emission coefficients for methane and nitrous oxide were derived from the Statistics Finland Greenhouse gas inventory (Statistics Finland 2017a). The air pollution emission coefficients were estimated based on the SYKE land report (Finnish Environment Institute 2017a).

Non-energy-based emissions are usually concentrated in a few rare sites, though in addition, there are smaller emissions dispersed in large areas, which are difficult to assess. The main source for the greenhouse gases was the emission inventory CRF calculation workbook (Statistics Finland 2017b), and for air pollution the SYKE calculation workbook (Finnish Environment Institute 2017b). When the energy-based and other emissions for each industry are added up, the result is the total amount of emissions of the industry. As for the use of raw materials, the emission coefficients for imported products have been estimated in the form of life cycle emissions based on the Ecoinvent data bank and other data sources for life cycle assessment.

Material flow analysis

The material flow analysis (MFA) is based on material flow accounting which gathers information on the amount of solid resources in nature which humans extract, convert or transfer for their activities (during a certain period of time). Material flow accounting measures material flows using the mass, a basic physical property which all substances have in common. The operating unit used is often the national economy, but any area or economic industry may be examined. When natural resources are extracted, material flows are divided into used and unused extraction. Used extraction indicates the amount of material transferred for processing or use in the economy, and unused extraction indicates natural material which is converted and transferred in connection with used extraction, but which remains in the environment in an unexploited form. Used extraction is also called direct material input, and unused extraction is called a hidden material flow.

The direct material input (DMI) of the national economy consists of the amount of material extracted from Finnish nature and the direct amount of imported material. The direct material consumption (DMC) is derived by deducting the amount of exported material from the direct material input. Direct material consumption indicates how much material – which is either stored in the capital stock, goods storages and landfills in the form of waste, or emitted in the atmosphere, the soil or waterways in the form of emissions – is accumulated in the economy during the year. However, the amount of material indirectly used for manufacturing exports goods will remain in the direct material consumption.

Once the mass of all raw materials extracted from nature, required for the manufacturing chains of products, is added to the amount of materials for import and export products, a reference may be made to raw material equivalent material flows. In this case, the import and export flows are symmetrical with the domestic material inputs. The raw material requirement (RMR) in the economy includes the import of the raw material equivalent and the raw materials extracted from domestic nature. When features such as the use of raw materials for household consumption or public procurement are examined, the RMR indicates in millions of kilogrammes the amount of materials commissioned in Finland and abroad, required for the manufacturing chains of the product or service groups concerned. The use of raw materials may be divided into the raw material used for exports and raw material consumption (RMC) which indicates how much natural raw materials were required for the domestic final use, consumption and gross capital formation.

The total material requirement (TMR) of natural resources is obtained when unused extraction, created in connection with the used extraction of natural resources, is added to used extraction. Total use may be divided into domestic and imported sections on the supply side. As for the total material consumption (TMC) of natural resources, it indicates to what extent the total use of natural resources is directed to domestic final use or consumption and investments. The ENVIMAT model is used to calculate which manufacturing and supply chains for various end products used material flows imported in Finland and extracted in Finland. Thus, material flows may be allocated to different final use categories.

2.2 Public procurement

Monetary data of public procurement

In this study, public procurement includes purchases of products and services by the state, municipalities and associations of municipalities as well as gross investments. It should be noted that public procurement is not the same as government consumption expenditure in the national accounts. The state procurement expenditure have been collected from the state reporting service Netra (www.netra.fi), which provides budgetary procurement expenditure by main category of the state budget. There are a total of fourteen main categories or administration branches to be examined. The procurement is divided into 67 products and services (see Appendix 1), which comprise four procurement groups (materials; goods and supplies; leases; purchases of services and other expenses).

The procurement expenditure of municipalities (317) and associations of municipalities (146) have been obtained from a database maintained by Statistics Finland, which contains the financial data reported by municipalities and associations of municipalities. Expenditure type breakdowns are available with the accuracy of 34 products and services (see Appendix 1). Furthermore, they form three procurement groups (purchases of other services; materials, supplies and goods; as well as external rental costs).

Data on investment procurement have been obtained from Statistics Finland's national accounts, in the statistics on gross fixed capital formation of general government. The investments are divided into central and local government categories and into nine investment product groups. The state investment data specific to branches of administration, collected from Netra, covered only approx. 20% of the gross investments recorded in the national accounts. In the case of municipalities and associations of municipalities, the financial data reported to Statistics Finland covered approximately 87% of the gross local administration investments in national accounts. In addition, some of the reported investments would have been difficult to allocate to investment product groups. For these reasons, it was decided to assess the carbon footprint of public investments and the use of raw materials on the basis of national accounts. The use of deficient material would have led to a lack of understanding of the environmental impacts of investments.

Carbon footprint and raw material use of public procurement

The study examined the environmental burden of public procurement in terms of greenhouse gas emissions (GHG, unit: kg CO2e) and the raw material requirement (RMR). Life cycle GHG and RMR load coefficient estimates were estimated for the product groups of public procurement, using the ENVIMAT model. The model is first used to calculate the load coefficients for the average products on the Finnish market, categorised in ENVIMAT into 229 product groups. The load coefficients for domestic and imported products are weighted together using the import percentages of the domestic market. The ENVIMAT model produces coefficients per basic price value of products. From these coefficients, the load coefficients for purchase-priced products have been derived by adding the added cost of trade and transportation to their value, and by adding the added load of trade and transportation to the loads. The shares of trade and transports in the value of products have been obtained from Statistics Finland's 2014 input-output tables, whose product distribution is coarser (60 products) than that of ENVIMAT.

In central and local government accounts, goods in particular are more roughly divided than in the ENVIMAT model. This is why the more detailed load coefficients of the ENVIMAT model will be allocated for procurement products using the 2015 intermediate use data of the ENVIMAT model 'public sector' (i.e. industries with a majority of public operators). Load coefficients are obtained for each public procurement product group by using the proportional percentages of the amount of intermediate use of the ENVIMAT products included in a single product group for weighting. For approximately one half of the ENVIMAT products in the public sector, the percentage of use is zero, which is why the data for 123 products is used for the calculation. In the absence of detailed information on the distribution of intermediate consumption in the ‘public sector’, the same product-specific sums have been used for the weighting of the load coefficients of both state and municipal administration.

The load coefficients of ENVIMAT products are allocated to the procurement of state and municipal administration (municipalities and associations of municipalities) using a separate calculation key. Each ENVIMAT product is allocated to at least one procurement product in the state or municipal sector. The industry and product classifications of Statistics Finland (Statistics Finland 2008), Guidelines for the collection of information on municipal finances (Statistics Finland 2017f), the State Treasury business accounting chart (State Treasury 2015) and accounting material containing procurement information have been used for allocation. At the final stage, the procurement sums shall be multiplied by the load efficient, item by item, and the outcome will be life cycle greenhouse gas emissions (i.e. carbon footprint) and the use of raw materials.

The combustion emissions from the fuel and lubricants for public procurement have been assessed using energy consumption table specific to industry in the ENVIMAT model, the fuel price data exclusive of VAT and the fuel emission data. No detailed information is available on the content of the fuel and lubricant procurements per type of fuel by the state, by the municipalities and associations of municipalities. For this reason, the petrol, diesel and light fuel oil carbon dioxide emissions were calculated for each euro spent. The coefficients obtained were used to form a general emission coefficient by weighting the fuel-specific coefficients using the 2015 energy consumption data in the ‘public sector’ (i.e. industries with a majority of public operators) of the ENVIMAT model. The resulting combustion emission coefficient was used to multiply the fuel and lubricant procurement expenditure for each public procurement organisation. These emissions will be added to the calculated emissions in the fuel and lubricant manufacturing and distribution chains, which will result in the life cycle GHG emissions which also include the use of fuels.

The carbon footprints and the use of raw materials in public sector investments are calculated slightly differently compared to the procurement expense loading. The weighted GHG and RMR loading coefficients are calculated for the investment products (9 types) of Statistics Finland's national accounts. The waiting database is the product * investment goods group - gross investment matrix, estimated for the 2015 input-output model. The calculation uses the load coefficients for 57 ENVIMAT product groups. Investment loads are obtained by multiplying gross investments by the weighted coefficients.

2.3 Household consumption

Household consumption expenditure materials

In this study, the carbon footprint of household consumption has been examined based on both the national accounts and consumption research. The statistics for private consumption expenditure in the national accounts were used to compile the 2000-2016 consumption expenditure with the accuracy of 59 commodities. The consumption expenditure of foreign consumers in Finland was deduced from the consumption expenditure data. For 2014-2016, the consumption expenditure of foreign consumers in Finland were estimated using the 2013 distribution, since more detailed information was not available. Finally, household consumption expenditure was converted to the 2015 price level. Thus, the 2000-2016 households consumption expenditure was obtained at the 2015 price level. Consumption expenditure may be examined on various aggregation levels by commodity group (for example, on the level of 4, 13 or 16 commodity groups or on the calculation level of 59 commodities).

The most recent Statistics Finland consumption research material dates from 2016, and it consists of the responses from 3,673 households. The weighted responses, processed using the weighting coefficients calculated for the material by Statistics Finland, indicates consumption in Finnish households. According to Statistics Finland (2018), the basic population of the consumption study includes those permanently residing in Finland (the so-called household population). The basic study population does not include the institutionalised population, such as those living in care facilities. In 2016, the household population consisted of 5.3 million people. In national accounts, the consumption of private individuals is included in household consumption expenditure regardless of whether these individuals are part of the institutionalised population or another population group. In other words, the national accounts cover the consumption of a larger group of people compared to the basic population in the consumption study.

In addition to the differences related to the basic population, the data collection methods of the national accounts and the consumption study are different. The key difference in data collection is the fact that the material in the consumption study is collected as a sample study. Households are interviewed and they collect receipts for the purchase of convenience goods for 14 days. The national accounts are compiled using several data sources and statistics. The consumption study is also used as a data source for the accounts.

The expenditure indicated in the consumption study is smaller than the consumption expenditure for households according to the national accounts. In 2016, the consumption expenditure of households was, according to the consumption expenditure study, a total of EUR 34,191 per household, and according to the national accounts, EUR 42,070 per household (Statistics Finland 2018, Table 11).[1] In addition, the difference between the expenditure derived from the consumption study and other data sources is particularly significant for some categories of consumption expenditure, such as alcoholic beverages. The study divides the consumption expenditure for the consumption study into 69 groups of commodities according to the COICOP classification. Compared to an examination based on the national accounts, the number of details have been added in terms of housing and related energy use.

[1] Statistics Finland has unified the figures mentioned above in terms of their definitions. This has been explained in more detail in the consumption study handbook, p. 38.

The consumption-based study is based on the purchaser's price. In this case, product taxes and subsidies as well as trade and transportation margins are added to the basic product price. Similarly, the environmental impacts of trade and transportation are added to the environmental effects. Household consumption is generally measured in terms of household consumption expenditure or the commodities purchased by households. The national accounts also follow the broader concept of 'actual household consumption', where the services offered to households and paid for by the public sector and private non-profit organisations (the so-called third sector) are added to the household consumption expenditure. This concept describes the total value of goods and services used by households more comprehensively than household consumption expenditure. Actual household consumption is better suited for international comparisons than household consumption expenditure, since the distribution of the costs of services used by households (e.g. healthcare and education) between households and public sector varies between different countries. This report only focuses on household consumption expenditure, and the services produced by the public sector and the so-called third sector have been excluded from the examination.

Carbon footprint and raw material use of households

The ENVIMAT model calculates GHG and RMR load coefficients for 62 commodities. As the aggregation of commodities differs between the ENVIMAT model and the statistics on private consumption expenditure, the most detailed examination level of household consumption carbon footprint and raw material use in an examination based on national accounts (the so-called calculation level) is 59 commodities. The calculation level of consumption study is 69 commodities. For this level of accuracy, emission coefficients have been estimated for housing and related energy use commodities using various statistical sources. The carbon footprint of commodities and the use of raw materials are calculated by multiplying the sums in euros by the corresponding emission coefficients.

For the carbon footprint time series of household consumption, annual GHG emission coefficients were calculated for commodities for the 2015 consumption level, using the ENVIMAT model. The model has actually been estimated for 2015. Air pollution emissions in particular vary annually, mainly due to the changes in heating needs and energy production methods. Measures to combat climate change may also have reduced some emissions. For this reason, data on the development of significant emission factors in household consumption expenditure for 2000-2016 was compiled in the ENVIMAT database so that the changes could be entered in the model calculation. These factors included the distribution of primary energy use in the production of electricity and district heating, the consumption of heating energy in the intermediate use of rental housing and flats, the percentages of imported electricity and the percentages of bio-fuel for transport. In addition, an estimate was made of the changes for certain specific conditions which have significantly changed during the examination period (nitrous oxide emissions from fertiliser manufacturing, methane emissions from landfills and F-gas emissions from retail trade). However, these changes only apply to domestic emissions, since corresponding changes are not available at Ecoinvent for imported products.

Structural decomposition analysis

The structural decomposition analysis (SDA) may be used to break down the change in the combined effect of an entity consisting of several components and their different impact coefficients into different components. The overall change occurring over time in the carbon footprint of household consumption may be examined through the change in consumption expenditure, a change in the consumption structure and technological change (i.e. emission coefficients). The examination level of the structural decomposition may be on the overall level of the carbon footprint or on the various aggregation levels of the commodity groups. The change is examined between two sets consisting of two years each. These may be consecutive years or longer-term start and end years. If a longer period is examined, the SDA method divides the net change between the start and end years into components but cannot estimate in more detail the changes occurring during the examination period. These changes may have had effects leading in different directions. For this reason, the structural breakdown into sets of two years provides additional information on the change in the carbon footprint.

The structural decompostion formula for the overall change in the carbon footprint has been derived from the Dietzenbacher and Los model using averages (1998) (see also Miller & Blair 2009):

$$\Delta E = E_t - E_0 = \bar{\boldsymbol{e}}'\bar{\boldsymbol{r}}\Delta Q + \bar{\boldsymbol{e}}'\bar{Q}\Delta\boldsymbol{r} + \bar{\boldsymbol{q}}'\Delta\boldsymbol{e}, \tag{1}$$

E: where ΔE is the overall change in the carbon footprint (Mkg CO2e) between the start year (0) and the end year (t), $\boldsymbol{e}$ is the vector of the GHG emission coefficients (kg/€), $\boldsymbol{q}$ is the vector of commodity expenditure (M€), $\boldsymbol{Q}$ is the sum of household expenditure and $\boldsymbol{r} = \boldsymbol{q}/\boldsymbol{Q}$ is the vector of commodity expense percentages (€/€). Δ is the difference between the values of the end year and the start year, i.e. the change, the upper line refers to the arithmetic mean of the start and end year values, and ' refers to the transposed matrix of the vector. In equation (1), the first component on the righthand side is the effect of the change in consumption expenditure, the second component is the effect of the change in consumption structure, and the third component is the impact of the technological change in the overall change of the carbon footprint.

2.4 Uncertainty of the results

The results of this study on the carbon footprint and the use of raw materials are based on the load coefficients calculated for commodities, and on commodity-specific consumption expenditure. The life cycle load coefficients for commodities have been estimated using the environmentally extended ENVIMAT input-output model. In the model, domestic operations and imports form the overall environmental impact of the Finnish economy, which may be allocated to the domestic final use (incl. individual and government consumption and investments) and exports.

The uncertainties of the methods used consist of errors in the source data (material and monetary flows, consumption expenditure data, public procurement expenditure data, emission data), the conversion matrices used (combining ENVIMAT products with public procurement product groups) and the structure of the model itself (effects of the model's monetary allocation on the final results).

In public procurement, the calculation of the life cycle emissions of fuel and lubricants contains uncertainties. The background assumption is that the fuel consumption of all public organisations is similar in structure. In addition, it is not known at what price the organisations purchased fuel and lubricants. Instead, the average prices for 2015, exclusive of VAT, as reported by Statistics Finland, have been used in the calculations. In its entirety, the emission coefficient for public procurement fuels and lubricants (incl. manufacturing chain and combustion emissions) is very close in size to the coefficient used for household consumption. However, the combustion emissions of public organisations include neither the so-called process emissions resulting from the use of lubricants nor all fuel use related to national defence (e.g. jet fuel), which results in a slight underestimation of the GHG emissions from public procurement.

The carbon footprint of household consumption and the use of raw materials for 2015 are described in both the results for the ENVIMAT model (Chapter 3.1) and in a more detailed household analysis (Chapter 3.3). The figures are not comparable as such, since the source data and calculation methods used differ from each other to some extent. In the ENVIMAT model, the greenhouse gas emissions from household consumption and the use of raw materials are calculated directly on the basis of ENVIMAT products without converting them into commodities according to the COICOP classification. In addition, the consumption expenditure of foreign tourists in Finland (included in exports) are processed separately from household consumption expenditure. For the time series analysis, ENVIMAT products are converted into commodities, which causes uncertainty. In addition, it is necessary to deduce the consumption expenditure of foreigners in Finland from private consumption expenditure by means of estimation. However, the magnitude of the environmental load is similar in both calculation methods. In the results of the ENVIMAT model, the different final use categories are comparable, as are the different years in the carbon footprint time series for household consumption.

In the structural decomposition analysis, the level of aggregation of the commodities in the examination will have an effect on the contribution to the total change, which can be explained by a change in consumption expenditure and a change in the consumption structure. When the carbon footprint is examined by commodity group, the significance of the change in the consumption structure is overemphasised at the expense of the change in consumption expenditure compared to a calculation examining the carbon footprint as a whole. In addition, in the analysis, the impact of the structural change in consumption on total emissions is a so-called net impact; the simultaneous changes in opposite directions occurring in the consumption expenditure structure may remain unidentified. In the time series analysis of the carbon footprint of household consumption, the selection of change parameters and the quality of the source data for estimating the parameters may also cause errors in the results. Since no time series similar to that available for domestic production has been available for the GHG coefficients of imported products, the changes in the carbon footprint of households indicated above all changes in domestic production.

3 Results

3.1 National greenhouse gas emissions and use of natural resources in 2015

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The life cycle greenhouse gas emissions and the use of raw materials in the Finnish economy can be examined from the viewpoints of both supply and use. The global environmental impacts of the entire national economy consist of the combined effects of domestic production and imports. These two entities form the supply side. The domestic activities include the environmental impacts of the production and service sectors operating in Finland and the direct impacts of households. Imports described the life cycle environmental impacts of products manufactured abroad, including direct and indirect manufacturing effects. Use includes domestic final use and exports. Domestic final use consists of private and public consumption and investments.

In 2015, the life cycle greenhouse gas emissions caused by the Finnish national economy totalled 125.8 million tons of CO_2e (Figure 2). This is approximately 128% more than the greenhouse gas inventory reported for that year under review, i.e. Finland's official emission figure (55.2 Mt CO_2e, Statistics Finland 2019). Imports accounted for 53% of life cycle greenhouse gas emissions, and domestic production accounted for 47%. Thus, more than one half of GHG emissions are generated outside of Finland's borders. Domestic production include approximately 3.9 Mt of fuel emissions from the international traffic of Finnish aircraft and ships (cf. Niemistö et al. 2019). These emissions are included in a production-based figures, but they are not summed up in the territorial figures (European Environment Agency 2013) on which the reporting of greenhouse gas emissions, or Finland's official emission figure, is based.

Regarding the global greenhouse gas emissions caused by the Finnish national economy, 73.4 Mt (58%) were allocated to domestic final use, or consumption and investments. These are also called consumption-based emissions (Nissinen et al. 2015, Salo et al. 2016). The remainder of the effects (42%) were allocated to exports, and it may be considered that they are allocated to private and public consumers and investments abroad.

Greenhouse gas emissions from domestic final use were approximately 24% higher than the emissions caused by domestic production, and approximately 33% higher than Finland's territorial emissions or official emissions. Domestic final use may also be referred to as Finland's carbon footprint.

Household consumption caused 48.6 million tonnes of GHG emissions or 66% of the emissions caused by domestic final use (which was 73,4 Mt). The rest of the domestic final use life cycle greenhouse gas emissions (34%) were due to public consumption and investments, and they were distributed as follows: non-profit organisations serving households, 1.1 Mt, public, individual consumption expenditure, 5.0 Mt, public, collective consumption expenditure, 4.1 Mt, gross fixed capital formation or investments, 14.2 Mt, and stock change, 0.3 Mt. Based on these figures, the carbon footprint of public consumption was 9.1 Mt, and its percentage of domestic final use was 12.4%. The percentage of investments was 19.3%.

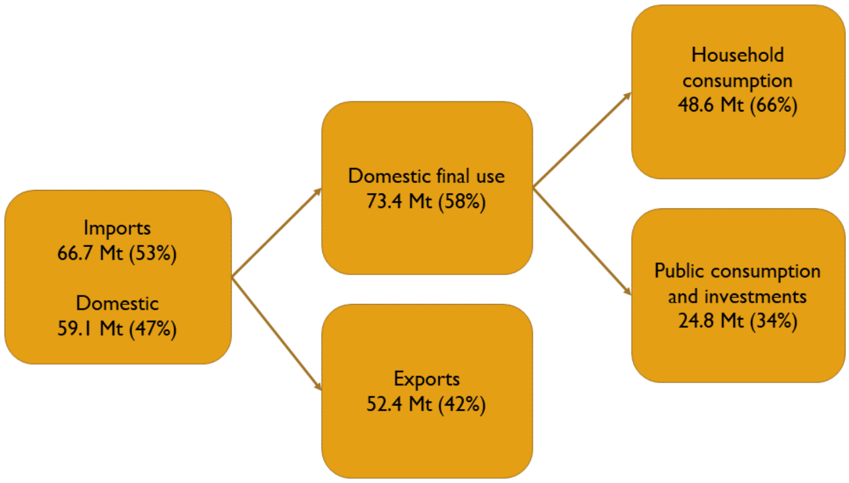

Figure 2. Greenhouse gas emissions of the Finnish economy (125.8 Mt CO_2e in total) divided by purposes in 2015. Domestic final use can be also seen as carbon footprint of Finland. The footprint was 33% bigger than the territorial emissions (55.2 Mt CO2e) which form the basis of the official national emission inventories.

The use of natural resources in the Finnish national economy, i.e. material flows extracted from domestic nature and coming from abroad in imported products, is presented in Figures 3 and 4. The total use of Finland's natural resources (total material requirement, TMR) in 2015 was 637 million tonnes (Figure 3). The total use of natural resources per person was 116 tonnes, and in relation to GDP it was 3.03 kg / EUR. Imports accounted for 62% of total use.

The direct material input from the Finnish nature was 170 Mt and hidden flows 73 MB, and the use of domestic natural resources totalled 243 Mt (Figures 3 and 4). The largest single material group was gravel and crushed stone aggregate, which covered approximately 53% of direct inputs and approximately 36% of the total use of domestic natural resources. Raw wood accounted for approximately 20% of the domestic used extraction and approximately 24% of total use and hidden flows.

The direct material input of imports was 54 Mt, the raw material equivalent imports were 173 Mt, and the total use of natural resources, including unused extraction, was 394 Mt (Figures 3 and 4). The large differences in masses reflect the high degree of processing of imported products. Taking into account the life cycle impacts, the overall use of imported natural resources will be high.

The largest product group of direct material inputs in imports was fossil fuels, approximately 38% of the imports. The second largest group was chemical products. When imported products were evaluated as raw material equivalent material flows, fossil fuels remained the largest product group, but basic metals became the second largest group by approximately 15%, even though the percentage of their direct material inputs accounted for only approximately 3%. When examining the total use of imported natural resources, the largest product group was basic metals with approximately 18%, and the second largest was fossil fuels with approximately 16%.

The ENVIMAT model can be used to analyse which production chains for different end products utilise material flows from the Finnish nature and imported to Finland. When looking at the overall use of natural resources, more than half of the natural resources were used to manufacture export products, less than a fifth to invest (including gross fixed capital formation and stock change) and more than a quarter to produce consumer goods and services (Figure 3). The total consumption of natural resources (TMC, total material consumption), i.e. the share of total consumption of natural resources which is used for consumption and investments, was 285 million tonnes (Figure 3). Correspondingly, when examining the use of raw materials, raw material consumption (RMC, i.e. the raw material flows required for consumption and investments) was 158 Mt (Figure 4).

The largest export product group, measured by direct material inputs (DMI), was wood and paper products with approximately 40%. When examining raw material equivalent material flows (RMR), the product group of basic metals emerged alongside wood and paper products. At the level of the total use of natural resources, the product groups mentioned above were also the largest, with both accounting for approximately 20%. The direct material volume of metal and engineering products was 1.1 million tonnes, but the total use of natural resources for the products was as high as 37 million tonnes. Similar significant differences were found in electronical products (DMI 0.3 Mt and TMR 28 Mt).

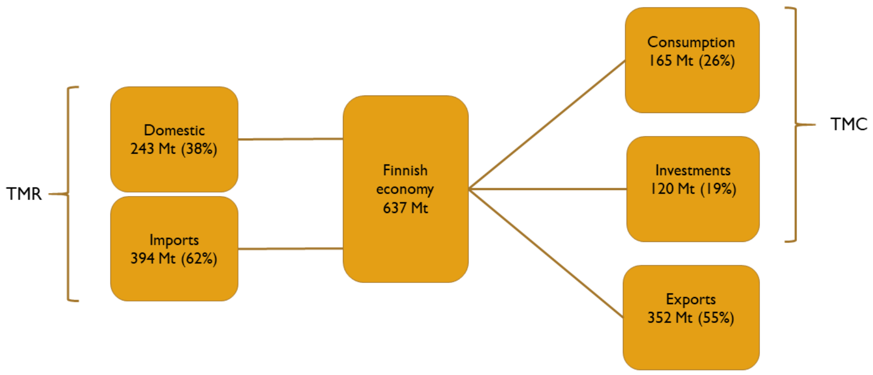

Figure 3. Total material requirement (TMR) in the Finnish economy in 2015. Total material consumption (TMC) equals the domestic use of TMR.

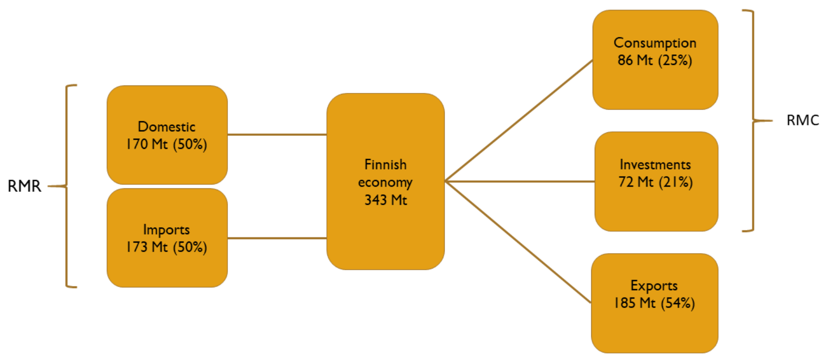

Figure 4. Raw material requirement (RMR) in the Finnish economy in 2015. Raw material consumption (RMC) equals the domestic use of RMR.

3.2 Value of public procurement, greenhouse gas emissions and use of raw materials

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3.2.1 Amounts of public procurement and investments by public sector

According to the data on public procurement, the municipalities making the most of the procurements in monetary terms were those whose procurements amounted to approximately EUR 10 billion in 2015 (Table 1, Chapter 3.2.2). The value of procurement by associations of municipalities was almost EUR 5 billion, and the amount of procurement by central government was also nearly EUR 5 billion. Gross investments, such as construction and machinery procurements, totalled EUR 3.6 billion in central government and EUR 4.7 billion in local government (municipalities and associations of municipalities). Thus, the total amount of government procurement and investments was EUR 8.5 billion. The total amount of procurement and investments by municipalities and associations of municipalities was EUR 19.8 billion. In other words, the amount of public procurement according to the data used in the study was EUR 20.0 billion, and the amount of gross investments was EUR 8.3 billion. Procurement and investments totalled EUR 28.3 billion. The reliability of procurement volumes will now be assessed from the perspective of both coverage and overlap.

Data coverage

The state's public procurement data was first compared to the intermediate use by the central government in national accounts. Procurement figures differ from intermediate use by public sector. In central government, intermediate use totalled EUR 6.17 billion. Thus, in central government, intermediate use was 27% higher than in the research material. In central government, intermediate use for public administration, education and health and social services amounted to EUR 4.96 billion, which is fairly close to the EUR 4.83 billion in the procurement data, with a difference of 2.3%. Intermediate use by the central government occurs for instance in technical services, scientific research and development, property and landscape management, catering, audiovisual and other real estate activities. Other central government units operating in these fields include off-budget funds, universities and limited liability companies supervised by central government units, which are non-market producers (Statistics Finland 2012). The procurement expenditure of these units is not included in the data collected from the NETRA system. When analysing state procurement, it is also justified that it is examined separately from the actual central government, as their steering for sustainable and low-carbon procurement is not as straightforward as that of the actual central government. On the other hand, some of the procurement outside the budget economy is regulated by the legislation on public procurement, and thus their procurement may need to be examined in further studies.

Valovirta et al. (2017, pp. 55-56) have assessed the volumes of central government procurement on the basis of Statistics Finland's data. In 2014, central government procurement of goods and services for its own use (intermediate use) totalled EUR 5.977 billion, and the purchased service production totalled EUR 0.341 billion (5% of the total procurement, excluding investments). The data for this study lacks the purchased service production mentioned above. However, the shortcoming may be considered rather small if it is assumed that the service production purchased in 2015 was of the same magnitude as in 2014.

The intermediate use of municipalities and associations of municipalities in national accounts for 2015 is EUR 15.75 billion. In other words, the difference in the data is approximately 4%, which may be considered relatively small. The procurement data of municipalities and associations of municipalities lacks the purchased service production presented by Valovirta et al. (2017). In practice, this is a procurement item for purchases of customer services from service providers other than municipalities, associations of municipalities or the state. In general, customer services are final product services intended for municipal residents that the municipality or association of municipalities purchases from other service providers (Statistics Finland 2017f). The purchased service production used by Valovirta et al. (2017) was EUR 2.99 billion in 2014. In the same year, purchases of customer services by municipalities and associations of municipalities totalled EUR 2.82 billion (6% difference). Overall, the purchased service production accounts for approximately 15% of local government procurement (excluding gross investments) in the report mentioned. Assuming that the volume of service production purchased in 2015 was the same in relation to all local government procurement as in 2014, the material therefore lacks approximately EUR 3.21 billion of procurement, or approximately 18% of procurement costs.

Calculated from statistics presented by Valovirta et al. (2017), the total goods and services procurement by central and local governments for their own use totalled EUR 22.47 billion in 2014, the purchased service production totalled EUR 3.33 billion, and the amount of investments was EUR 8.57 billion. The total amount was EUR 34.36 billion. The total amount of material used in this study is EUR 28.25 billion, which is of the same magnitude. Due to the differences mentioned above, the procurement volumes of the data are slightly lower, but, however, close to the figures presented for public procurement in recent years (see e.g. Lith 2014). It should be noted that comparing consecutive years at current prices is misleading due to inflation. Moreover, the years examined may differ due to the general economic situation or timing of large procurement decisions.

In terms of coverage, the procurement of companies owned by municipalities and associations of municipalities are a problematic item. These procurements are not reported in connection with the expense-type breakdowns for the operating economy of municipalities and associations of municipalities, even though the companies may be part of the municipal group. The intermediate use of such companies is statistically recorded in the sector of the companies according to their industry (Statistics Finland 2012). It was not easy to distinguish the data of public undertakings controlled by public sector from the data of other private companies.

Possible overlap

The assessment of the carbon footprint of procurement is based on procurement expenditure in euros. For this reason, it is important to assess the extent to which the data used includes internal and cross-sectoral procurements by the state, municipalities and associations of municipalities. Possible overlaps in euros (procurement of services in one place and procurement of goods needed for their implementation elsewhere) cause overlapping in the calculation of emissions and thus an overestimation of the carbon footprint and raw material use of public procurement.

The central government accounts distinguish between purchases of services from government agencies and institutions and from other parties. Thus, there is no overlapping calculation in the examination of central government administrative branches. However, it cannot be excluded that some of the central government's procurement is targeted at municipalities and/or associations of municipalities. However, the aggregation level of the data used is not sufficient to ensure this.

For municipalities and associations of municipalities, overlapping procurement is clearly a larger problem. Firstly, the intermediate use purchases of enterprises and the service fees or rents paid by the municipality or associations of municipalities to enterprises have not been cleaned (at least not in their entirety) from the statistics on the expense types for the operating economy of municipalities and associations of municipalities. Such internal purchases and sales are recorded in the operating economy data, if the purchase cost and sales revenue are in different task categories (Statistics Finland 2017f). This is the case for enterprises providing support services, for example. According to the statistics on the operating economy, for municipalities, such internal overlaps may amount to as much as 22% of all procurement expenditure (excluding gross investments). Similarly, internal overlaps are 17% for associations of municipalities.

Secondly, the overlapping of procurement expenditure is caused by municipal service procurement from other municipalities and associations of municipalities, and by service procurement made by associations of municipalities from other associations of municipalities and municipalities. Based on an analysis of the statistics on operating economy, it can be estimated that 6% of the purchases of municipal services within the material used are targeted at services sold by municipalities and 16% by associations of municipalities, causing overlapping. Similarly, 10% of the service purchases made by associations of municipalities are allocated to municipalities and 3% to associations of municipalities.

Overall, the share of overlaps in municipal procurement (excluding gross investments) can be as much as EUR 3.72 billion, or approximately 37%. In associations of municipalities, overlaps can be EUR 1.19 billion, or about 24% of procurement.

Summary

The data used in this study describes public procurement, including investments, quite comprehensively. Compared to the report by Valovirta et al. (2017), the material currently used lacks the purchased service production of the state, municipalities and associations of municipalities. In addition, the material lacks the procurement information on other central government units. However, the material used in the study contains the most clearly controllable part of the procurement. The procurement expenditure of municipalities and associations of municipalities in particular have problems related to the method used for compiling statistics, the resolution of which requires the development of the operating economy statistics in Statistics Finland.

It would be difficult to calculate the carbon footprint and raw material use of purchased service production if this procurement expenditure was included in the material used. Statistics on service expenses have not been broken down in more detail. If this were done, significantly broader estimate would have to be used when assessing the emission coefficient. This would create uncertainty in the results.

It has been possible to estimate the magnitude of overlaps in euros, but it is difficult to assess the overlapping carbon footprint and raw material use based on the data available. However, it is known that the overlap concerns the purchase of different services. The emission coefficients of the services are lower than the coefficients of supplies procurement (excluding the RMR coefficients of construction services). In other words, it can be assumed that the carbon footprint and the use of raw materials would not decrease in proportion to the procurement expenditure, but that the reduction would be lower than the above-mentioned percentages.

3.2.2 GHG emissions from public procurement and the use of raw materials

Overview of the carbon footprint of public procurement

This chapter presents estimates of the carbon footprint of public procurement, i.e. life cycle greenhouse gas emissions. In this context, it is worth bearing in mind the uncertainty related to the procurement volumes expressed in the previous chapter, and the uncertainty related to the product-group-specific emission coefficients expressed in Chapter 2. In addition, the carbon footprint is not the correct word for all product groups (see glossary), but it can be considered suitable especially for organisation-specific examination, in which emissions from the fuel use phase and waste management are included.

Despite the uncertainties, the results can be considered so far the best available assessment of the carbon footprint of public procurement.

In 2015, the carbon footprint of public procurement totalled 8.3 million tonnes of carbon dioxide equivalent (Table 1, Figure 5). Of the emissions, 1.78 Mt was caused by state procurement, 4.73 Mt by municipal procurement and 1.79 by procurement by associations of municipalities. Considering that there may be some overlap in the procurement volumes of municipalities and associations of municipalities (see previous chapter), it can be said that the carbon footprint was no more than 8.3 Mt, and the state's share of the carbon footprint was at least 21.5%, and the combined share of municipalities and associations of municipalities was no more than 78.5%. However, this uncertainty is not presented in the text below. Instead, the figures are presented as such.

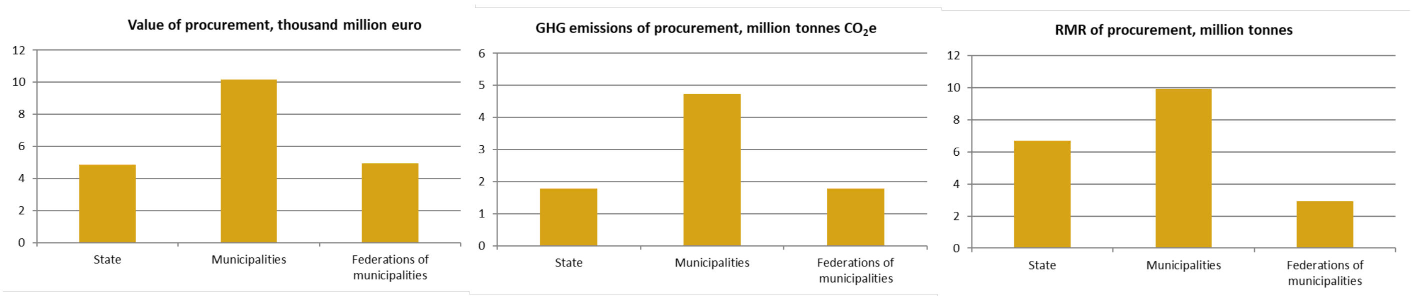


Figure 5. Value of public procurement, greenhouse gas emissions (GHG), and raw material requirement (RMR) in 2015.

Of the municipal emissions, 3.33 Mt were caused by the procurement of urban municipalities, 0.69 Mt by densely populated municipalities, and 0.71 Mt by rural municipalities. The emissions of associations of municipalities were as follows: hospital districts 1.03 Mt, other associations of municipalities for healthcare 0.12 Mt, associations of municipalities for social welfare 0.03 Mt, associations of municipalities for education 0.26 Mt, and other associations of municipalities (e.g. waste, water, electricity, transport, urban planning and administration) 0.34 Mt.

Table 1. Volume of public procurement, greenhouse gas emissions, and raw material requirement in 2015.

	Expenditure	Greenhouse gas emissions	Raw material requirement
	million euro	million kg CO_2e	million kg
State	4850	1780	6690
Municipalities	10160	4730	9910
Federations of municipalities	4930	1790	2930
Total	19950	8300	19530

Table 2. Greenhouse gas (GHG) and raw material requirement (RMR) intensities of public procurement per capita in 2015.

	GHG emission intensity	GHG emissions per capita	RMR intensity	RMR per capita
	kg CO_2e per €	kg CO_2e per capita	kg per €	kg per capita
State	0.37	330	1.38	1220
Municipalities	0.47	860	0.98	1810
Federations of municipalities	0.36	330	0.60	540
Total	0.42	1520	0.98	3570

State procurement calculated per person caused 320 kg of emissions, and municipalities and associations of municipalities caused 1,190 kg of emissions (Table 2). In total, the emissions from public procurement were 1,520 kg per person. The emission intensity (i.e. the amount of emissions in proportion to the amount of money spent) was the highest in municipalities, i.e. 0.47 kg CO_2e / €. For the state and associations of municipalities, this was clearly lower, i.e. 0.36-0.37, and the average for public procurement was 0.42 kg CO_2e / €.

Overview of the carbon footprint of investments by public organisations

In 2015, the carbon footprint of investments made by public organisations totalled approximately 2.7 Mt (Table 3), of which 1.01 Mt was the result of purchases by the state and 1.67 Mt by municipalities and associations of municipalities (local government figures were only available en bloc). The state share accounted for 38 per cent of emissions, and the share of municipalities and associations of municipalities was 62 per cent.

Investments made by state organisations calculated per person caused 184 kg of emissions, and municipalities and associations of municipalities caused 306 kg of emissions (Table 4). The total emissions were 490 kg per person. The emission intensity was higher in local government (0.36) than in central government (0.28), with an average of 0.32 kg CO_2e / €.

In total, the carbon footprint of public procurement and investments made by public organisations was 11.0 Mt, 75% of which was due to procurement and 25% to investments. The emission intensity was higher in procurement (0.42 kg CO_2e / €) than in investments (0.32 kg CO_2e / €).

Table 3. Volume of public organisation investments, greenhouse gas emissions, and raw material requirement in 2015.

	Expenditure	Greenhouse gas emissions	Raw material requirement
	million euro	million kg CO2e	million kg
State	3640	1010	9640
Municipalities and federations of municipalities	4660	1670	16090
Total	8300	2680	25730

Table 4. Greenhouse gas (GHG) emission and raw material requirement (RMR) intensities of public organisations investments, and related per capita figures in 2015.

	GHG emission intensity	GHG emissions per capita	RMR intensity	RMR per capita
	kg CO_2e per €	kg CO_2e per capita	kg per €	kg per capita
State	0.28	184	2.65	1760
Municipalities and federations of municipalities	0.36	306	3.45	2940
Total	0.32	490	3.10	4700

Raw material use of public procurement and investments

In 2015, the raw material use caused by public procurement was 19.5 Mt (Table 1). The state's share of raw material use was 34%, and the combined share of municipalities and associations of municipalities was 66%. The use of raw materials for investments made by public organisations was 25.7 Mt. In total, the use of raw materials for public procurement and investments made by public organisations was 45 Mt.

Calculated per person, the combined raw material use of state procurement and investments in 2015 was 2,980 kg. The combined value for municipalities and associations of municipalities was 5,290 kg. In total, the use of raw materials for public organisations' procurement and investments was 8,270 kg per person. The intensity of raw material use (kg / €) for procurement was higher for central government (1.38) than for municipalities (0.98) and associations of municipalities (0.60), with an average of 0.98. The large RMR of state service procurement (Figure 6) is due to the high intensity of raw material in the repair and maintenance services of earthworks and water structures. For investments, the situation was the opposite to the situation for procurement, i.e. the intensity was higher in municipalities and associations of municipalities (3.45) than in state investments (2.65), with an average of 3.10.

The intensity of the use of raw materials in investments was thus approximately three times higher than in procurement, due to the large share of construction in investments. The state's lesser intensity compared to that of municipalities is explained by the relatively large share of intangible investments in state investments.

Carbon footprint of state procurement by procurement expense group and administrative branch

When examined by procurement expense group (i.e. by account group), the highest share of greenhouse gas emissions from state procurement, or 42%, was due to the purchase of services, while 38% were due to materials, supplies and goods (Figure 6). Rental costs accounted for 12% and other expenses for 8% of the emissions caused by state procurement. However, for substances, supplies and goods, the share of greenhouse gas emissions was much higher, i.e. more than three times the share in euros, whereas for the purchase of services, the share of emissions was 18 percentage points lower than the share in euros.

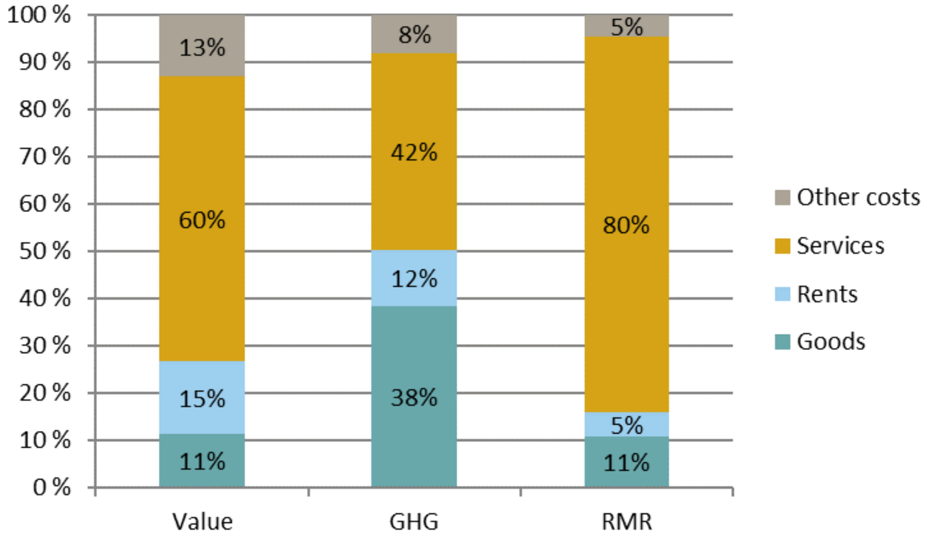


Figure 6. Shares of public procurement by cost category in 2015.

Among the administrative branches, the majority of the greenhouse gas emissions (i.e. 43%) was caused by the administrative branch of the Ministry of Defence, followed by the administrative branches of the Ministry of Transport and Communications (21%) and the Ministry of the Interior (10%) (Figure 7). Substances, supplies and goods caused the following shares of emissions in administrative branches: the Ministry of Defence 55%, the Ministry of the Interior 40%, and the Ministry of Transport and Communications 16%. Services accounted for 81% of emissions in the administrative branch of the Ministry of Transport and Communications, 38% in the administrative branch of the Ministry of the Interior and 26% in the administrative branch of the Ministry of Defence.

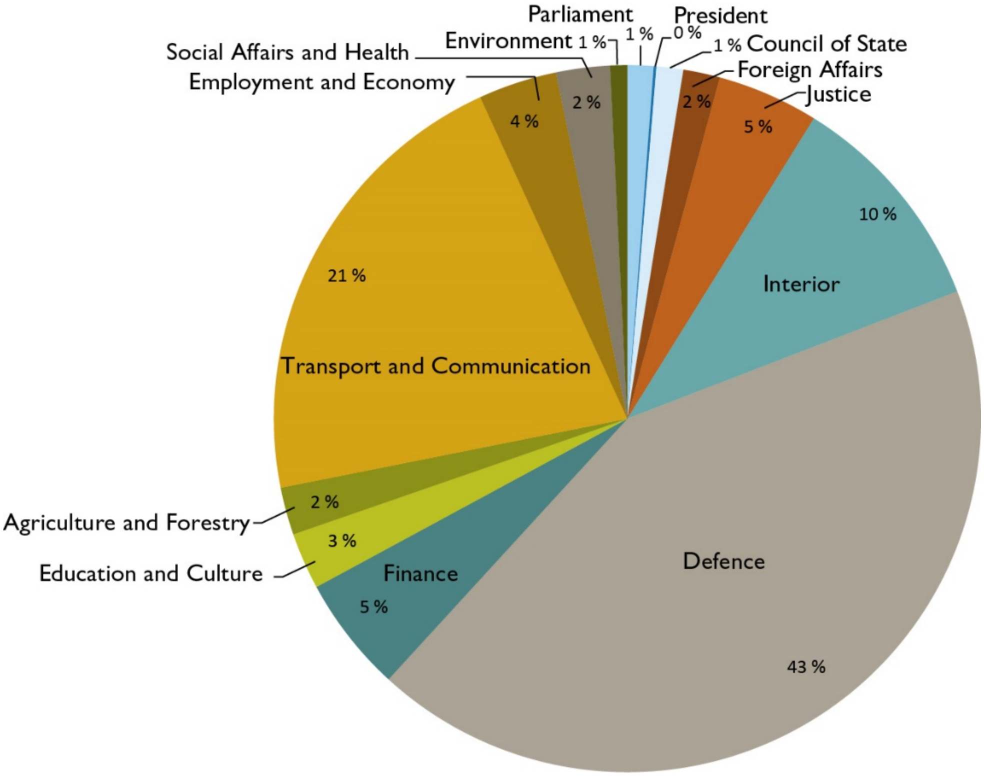
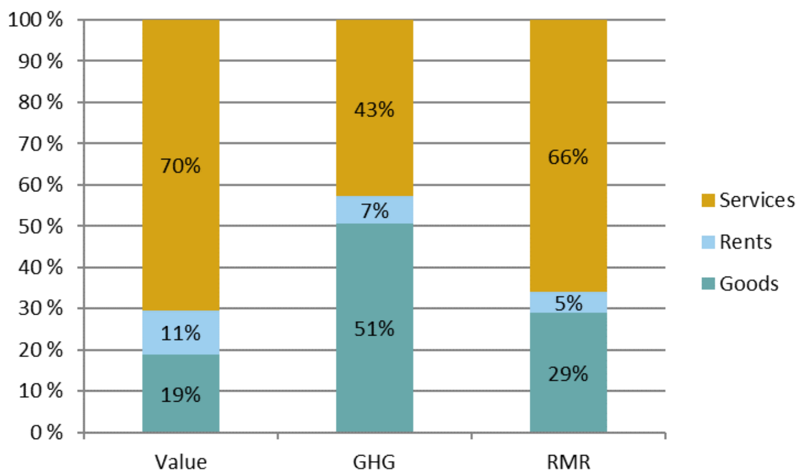


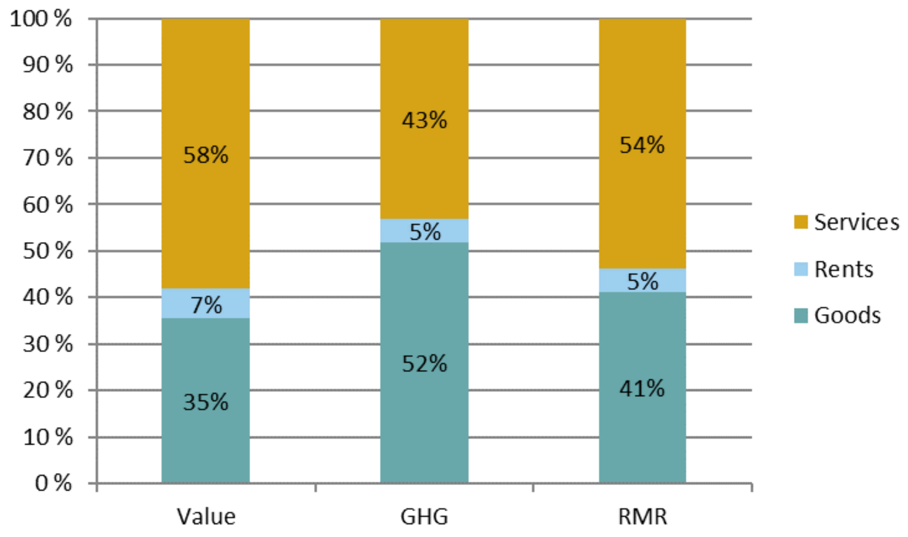
Figure 7. Greenhouse gas emissions of state public procurement by administrative branches in 2015. In total, the emissions were 1.78 Mt CO_2e.

Carbon footprint of procurement made by municipalities and associations of municipalities by procurement expense group

When examined by procurement expense group, 42% of greenhouse gas emissions from municipal procurement were caused by purchases of services, while substances, supplies and goods accounted for slightly more or 52% (Figure 8A). For substances, supplies and goods, the share of greenhouse gas emissions was 2.5 times higher than the share in euros, whereas for the purchase of services, the share of emissions was much lower than the share in euros.



8 A) Municipalities



8 B) Federations of municipalities

Figure 8. Shares of public procurement by cost category in terms of value, greenhouse gas emissions and raw material requirement in 2015. A) Municipalities, and B) Federations of municipalities.

43% of the greenhouse gas emissions from procurement by associations of municipalities was caused by purchases of services, while 52% are caused by service purchases, substances, supplies and goods (Figure 8B). When compared to municipalities, the picture of greenhouse gas emissions is similar, but in associations of municipalities, a considerably higher share of procurement consists of substances, supplies and goods, while the share of services is much lower than in municipalities.

Carbon footprint of state procurement by procurement expense type

The state had 67 procurement expense types (i.e. LKP accounts). Among these, ten procurement expense types caused more than 50 million kilograms (Mkg) of greenhouse gas emissions each. The largest state emissions were generated by the Heating, electricity and water category, 236 Mkg (i.e. 0.236 Mt). The most significant administrative branches for this category were the Ministry of Defence (121 Mkg) and the Ministry of Transport and Communications (47 Mkg). The Repair and maintenance services for earthworks and water structures category resulted in emissions nearly as large, 231 Mkg, and in this respect, the Ministry of Transport and Communications held first place with 228 Mkg in procurement emissions. The emissions of the Fuel and lubricants category were 207 Mkg, and the largest emissions were generated in the Ministry of Defence (146 Mkg) and the Ministry of the Interior (36 Mkg) administrative branches. The category of Rent from other buildings also generated substantial emissions, 189 Mkg, and among the administrative branches, the Ministry of Defence (42 Mkg), the Ministry of Justice (29 Mkg) and the Ministry of the Interior (29 Mkg) were highlighted. The category of Other external services caused 151 Mkg of emissions, and the Ministry of Transport and Communications caused 54 Mkg, the Ministry of the Interior 44 Mkg, and the Ministry of Defence 31 Mkg of emissions. The second ‘dumping category’ of Other substances, supplies and goods caused 136 Mkg of emissions, of which 97 Mkg were caused by the administrative branch of the Ministry of Defence, and 14 Mkg were caused by the administrative branch of the Ministry of Social Affairs and Health. The Expert and Research Services category caused 125 Mkg of emissions, which was more evenly distributed among administrative branches than most other types of procurement expenses, as the largest emissions were generated in the administrative branch of the Ministry of Finance (27 Mkg) and the administrative branch of the Ministry of Defence (26 Mkg). The National Defence Equipment category caused 74 Mkg of emissions, and it was created entirely in the field of the Ministry of Defence. The emissions caused by the Repair and maintenance services of other machines and equipment category were 58 Mkg, of which 53 Mkg were caused by the administrative branch of the Ministry of Defence.

Carbon footprint of procurement made by municipalities and associations of municipalities by procurement expense type

There were 34 types of procurement expenses in municipalities. Among these, twelve procurement expense types caused more than 100 million kilograms (Mkg) of greenhouse gas emissions each. In municipalities, the largest emissions were generated by the Heating (799 Mkg) and Electricity and gas (745 Mkg) categories. The other larger categories included the following: Construction and maintenance services for buildings and areas (427 Mkg), Travel and transport services (374 Mkg), Foodstuffs (334 Mkg), Cleaning and laundry services (285 Mkg), Rent for buildings and apartments (272 Mkg), Accommodation and catering services (244 Mkg), dumping category Other services (166 Mkg), Other joint operations shares (151 Mkg), and Fuel and lubricants (144 Mkg). The emissions for the Office and expert services category were 125 Mkg.

There were also 34 types of procurement expense types in associations of municipalities. Among these, six procurement expense types caused more than 100 million kilograms (Mkg) of greenhouse gas emissions each. The largest emissions were generated in the Travel and transport services (292 Mkg) and Medicines and medical supplies (269 Mkg) categories. The next largest emissions came from the Heating (180 Mkg), Electricity and gas (157 Mkg), Cleaning and laundry services (114 Mkg) and dumping category Other services (105 Mkg).

3.3 The carbon footprint time series and structural decomposition analysis for household consumption and the use of raw materials for consumption

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Household consumption accounts for approximately two-thirds of Finland's consumption-based greenhouse gas emissions (see Chapter 3.1). In addition, households cause approximately a quarter of Finland's use of natural resources. It is therefore necessary to analyse in more detail which commodity groups cause the highest emissions and use of raw materials, which changes have occurred in the carbon footprint of household consumption in the 21st century, and what factors explain these changes.

3.3.1 Carbon footprint of household consumption in 2000–2016

Between 2000 and 2016, household consumption expenditure increased by 38%, from over EUR 81 billion[2] to over EUR 112 billion (Figure 8). The recession following the financial crisis is reflected in a decline in consumption expenditure in 2009 and subsequently in slower growth than at the beginning of the millennium. The carbon footprint of households increased by 12% during the studied period, but the annual variation was great. In 2000, lifecycle greenhouse gas emissions were 53.4 Mt CO_2e and in 2016,

[2] All figures in euros are expressed in fixed 2015 prices.

they were 60.1 Mt CO_2e[3]. The largest GHG emissions during the studied period were generated in 2007 (66.6 Mt CO_2e). From 2010 onwards, the carbon footprint decreased until it began to rise again in 2016.

In Figure 9, the territorial greenhouse gas emissions in Finland, in accordance with official emission statistics, are presented alongside the carbon footprint of households. They reached the peak of the studied period in 2003. Since then, the territorial emissions trend has been declining, although there have been some individual growth years. Territorial greenhouse gas emissions decreased by 16% between 2000 and 2016. The carbon footprint of households has not decreased in a similar way. The main reason is that some of the lifecycle greenhouse gas emissions of household consumption are generated in the production chains of products imported to Finland from abroad[4].

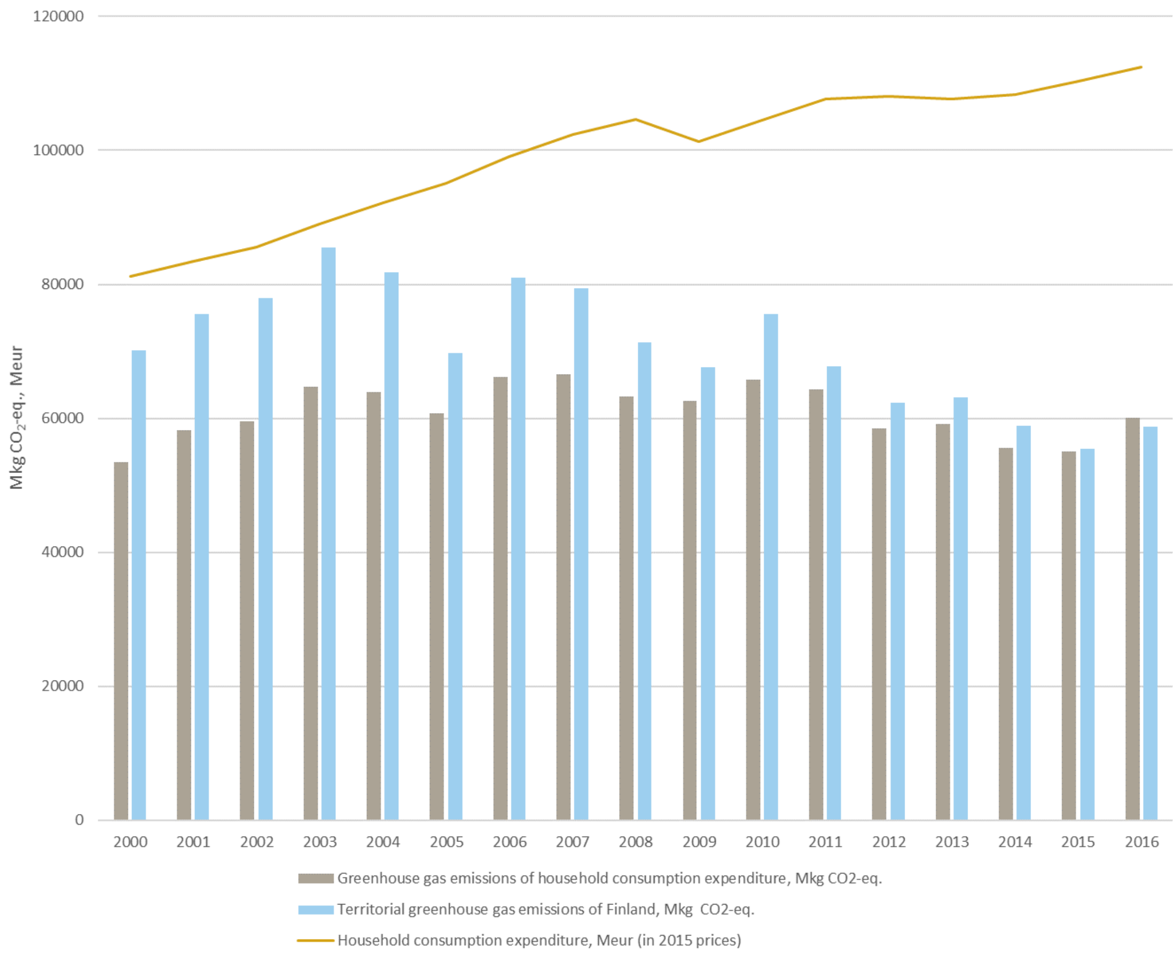

Figure 9. Household consumption expenditure and greenhouse gas emissions, and territorial greenhouse gas emissions in Finland in 2000–2016.

Figure 10 indicates the volume indices for household consumption expenditure and greenhouse gas emissions and for greenhouse gas intensity since 2000. Both consumption expenditure and the carbon footprint increased compared to 2000, but there were several years during which the carbon footprint

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[3] In 2015, GHG emissions amounted to 55.1 million tonnes, which differs from the 48.6 Mt mentioned in Chapter 3.1. The main reasons are the method (conversion of products into commodities) and material used (household consumption expenditure per commodity) when calculating the time series of emissions. See also Chapter 2.4.
[4] It is worth noting, that time series analysis concentrates mainly on the changes in domestic production. Similar time series is not available for imports. The share of imports in different consumption commodity groups varied between 17–82 % (mean 47 %).

increased more slowly than consumption expenditure or even decreased compared to the previous year. This kind of development can be called relative decoupling (UNEP 2011). It represents a slower or zero increase in the environmental impact compared to the development of the economy or expenditure. Greenhouse gas intensity is calculated by dividing greenhouse gas emissions by consumption expenditure. The decreasing trend of intensity from 2007 to 2015 describes the same phenomenon. The greenhouse gas intensity of household consumption was highest in 2003 (0.73 kg CO_2e / euro). The intensity decreased by 19% over the period examined.

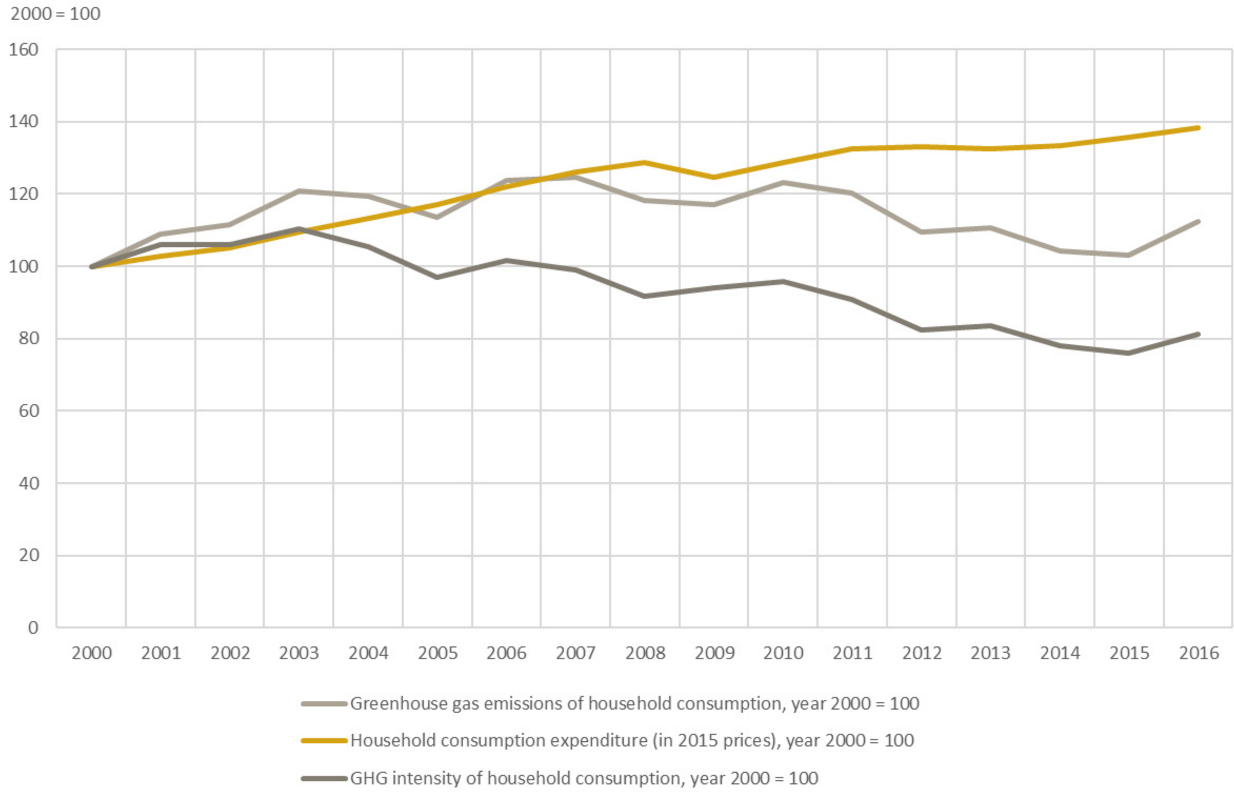

Figure 10. Household consumption expenditure, greenhouse gas emissions, and greenhouse gas emission intensity (volume index).

The carbon footprint of household consumption is also affected by population growth, which was 6% between 2000 and 2016. The GHG emissions of consumption per capita also increased by 6%. The impact of population growth can be eliminated by dividing consumption expenditure and the carbon footprint of consumption per capita. At the same time, the average carbon footprint of Finnish[5] consumption can be illustrated.

Between 2000 and 2016, the average carbon footprint per capita varied from 10.1 tonnes to 12.6 tonnes in Finland. The distribution of consumption and the carbon footprint remained largely the same during the period examined. Housing, transport and food form just over three quarters of the carbon footprint (Figure 11). These results are in line with numerous other analyses (including Salo et al. 2016, Ivanova et al. 2016 and Seppälä et al. 2011). In 2016, food and non-alcoholic beverages accounted for 19%, other goods and services for 22%, transport for 30% and housing and related energy use for 29% of the carbon footprint. Over the time period, the share of other goods and services of the emissions

[5] All people living in Finland are included in the population, and they are not all Finnish citizens. However, for the sake of readability, we use the word 'Finn' and not 'Finnish resident'.

increased the most (+35%), and the share of housing and its energy decreased the most (-9%). The greatest variation occurred in housing. This is explained by the use of energy from housing, which is affected by weather conditions, heating needs and the annual fuel distribution. In 2015, the population-weighted figure for heating needs was well below the average for the period examined, while the needs for 2016 were very close to the average. This is one of the key explanatory factors in the increase of the carbon footprint between 2015 and 2016.

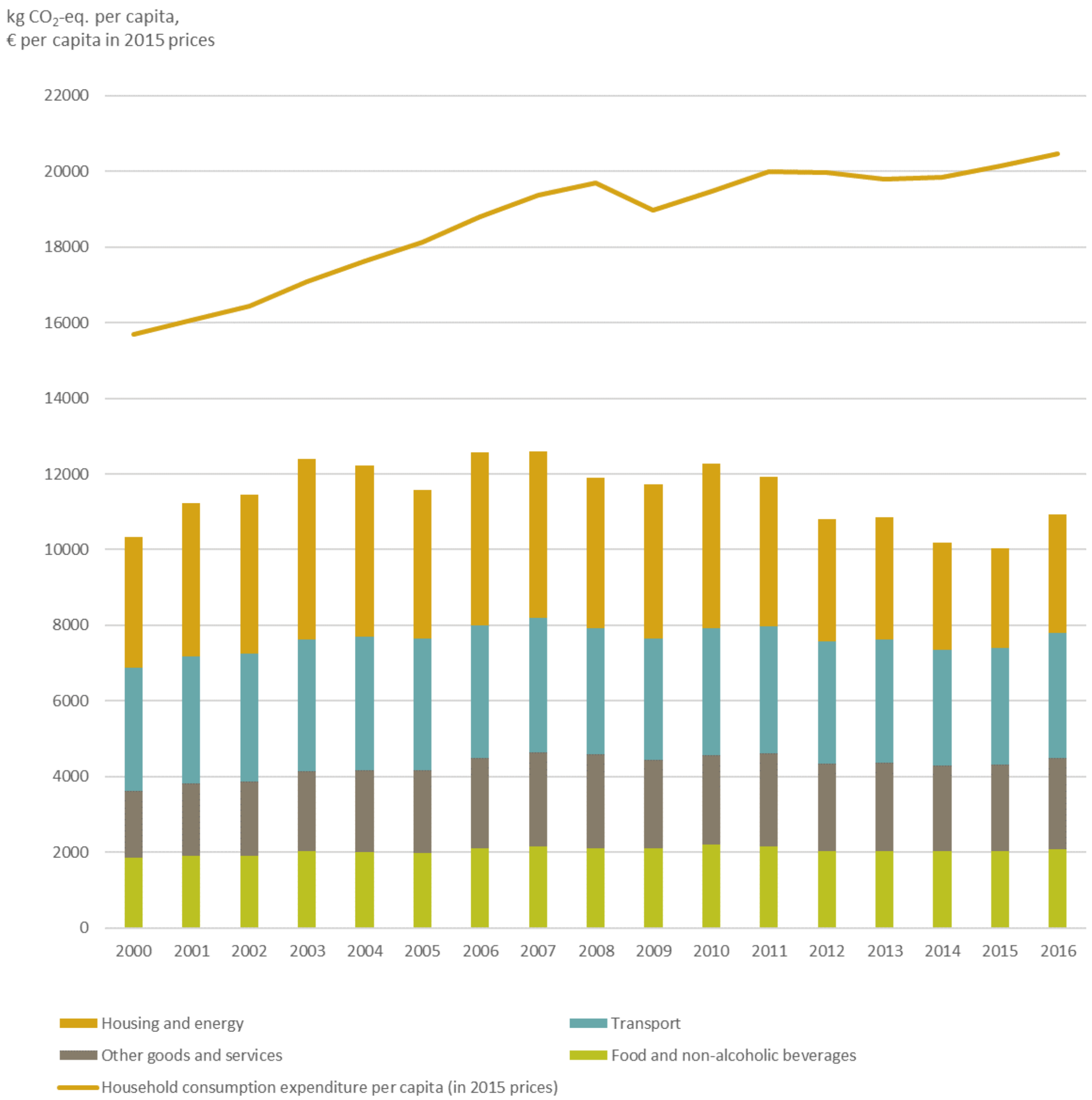

Figure 11. Average per capita consumption expenditure and carbon footprint of Finns in 2000–2016.

Commodities may also be grouped on grounds other than the COICOP classification. In thematic grouping, restaurant and meal services may be included in the food and package travel in transport. This is done e.g. in Sweden (Björk et al. 2018). In the material for this study, the commodities containing the services described above are placed in the category of *Other goods and services*. By means of an alternative breakdown ("Swedish model"), the share of *food* and *transport* in the carbon footprint increases slightly, and similarly the share of *other goods and services* decreases (Table 5).

Table 5. Average per capita carbon footprint of a Finn following two different approaches to make the grouping of goods and services.

	ENVIMAT model		Swedish approach		Difference		
	Emissions per capita	Share	Emissions per capita	Share	Emissions per capita	Change	Share
Commodity groups	kg CO_2e	%	kg CO_2e	%	kg CO_2e	%	percentage points.
Food	2 080	19%	2 435	22%	354	17%	3%
Housing and energy	3 132	29%	3 132	29%	0	0%	0%
Transport	3 313	30%	3 415	31%	102	3%	1%
Other goods and services	2 409	22%	1 953	18%	-456	-19%	-4%

A more detailed examination of the average consumption and carbon footprint of Finns reveals the connection between the amount of consumption in euros and the resulting carbon footprint (Table 6). Between 2010 and 2016, consumption of foodstuffs increased by almost 20%, while at the same time, emissions from *plant-based food items* increased by 10% and from *animal-based food items* by 15%. Among the sixteen commodity groups, *animal-based food items* were the third largest source of GHG emissions, although only 5% of consumption expenditure was allocated to them. *Housing and energy* were the most significant commodity group from the perspective of both consumption expenditure (28%) and emissions (24%). Although housing and energy expenditure increased by 18%, emissions decreased by 14%. The *furnishings, household equipment and services* in the same main category were of minor significance.

In mobility, the *use of private vehicles* accounted for 26% of the GHG emissions, but only 7% of the consumption expenditure were allocated to it. The use of fuel and lubricants was a key factor within the group. The increase in expenditure was 26%, but emissions only increased by 1%. This positive development was particularly explained by the increase in the biological share of transport fuels. For the *purchase of vehicles*, the change in consumption and emissions was significant (an increase of more than 30%), but the importance of the commodity group remained small due to the low share of both.

The Other goods and services main category is composed of a number of commodity groups. With regard to the carbon footprint, *recreation and culture* was the most significant group, with a share of 7%. *Clothing and footwear, communication and tourism expenditure abroad* increased in terms of both consumption expenditure and emissions, but in 2016 their shares were 1–2 per cent. While the expenditure on *education* and its emissions decreased clearly, the commodity group in question is the smallest in both monetary and emissions terms.

Table 6. Average per capita consumption expenditure and carbon footprint by commodity groups in 2016, shares in 2016, and change during 2000–2016.

	Consumption expenditure 2016	Change 2000–2016	Share 2016	GHG emission per capita in 2016	Change 2000–2016	Share 2016
Commodity groups	euro	%	%	kg CO_2e	%	%
Plant-based food items	1512	19%	7%	881	10%	8%
Animal-based food items	1105	18%	5%	1199	15%	11%
Alcoholic beverages and tobacco	882	-1%	4%	150	0%	1%
Clothing and footwear	812	54%	4%	262	50%	2%
Housing and energy	5670	18%	28%	2664	-14%	24%
Furnishing, household equipment and services	995	39%	5%	469	36%	4%
Health	885	39%	4%	143	36%	1%
Purchase of vehicles	680	38%	3%	114	34%	1%
Operation of personal transport equipment	1342	26%	7%	2887	1%	26%
Transport services	408	10%	2%	312	8%	3%
Communication	473	121%	2%	75	106%	1%
Recreation and culture	2108	31%	10%	761	45%	7%
Education	78	-18%	0%	11	-25%	0%
Restaurants, and hotels	1145	17%	6%	384	8%	4%
Other goods and services	1980	30%	10%	367	27%	3%
Tourism expenditure abroad	607	87%	3%	256	91%	2%
Total	20460	30%	100%	10934	6%	100%

3.3.2 Structural decomposition of the carbon footprint of household consumption

The carbon footprint of household consumption increased by 6,650 Mkg CO_2e between 2000 and 2016. This change in the carbon footprint can be divided into three factors: a change in consumption expenditure, a change in the consumption structure and technological change. An increase in consumption expenditure means an increase in emissions, as the emission coefficient of all commodities is higher than zero. The change in the consumption structure, on the other hand, describes the distribution of consumption into different commodities. As commodities have different emission coefficients, the change in the consumption structure will affect emissions. The technological change describes the change in the emission coefficients of different commodities. In this study, the technological change is caused particularly by energy-related changes (fuel distribution of electricity and heat production, share of imported electricity, biological share of transport fuels, etc., see Chapter 2.4 for more details).

In the components of the change in the carbon footprint, an increase in consumption expenditure alone would have increased emissions by 16,395 million kg CO_2e during the period examined (Figure 12, the components in the figure sum up to the overall change). A change in the consumption structure would have reduced emissions by 3,061 Mkg CO_2e. In 2016, a proportion of consumption expenditure which was smaller than before was allocated to *housing and energy* as well as *fuel and lubricants*. As these emission coefficients for commodities are high and, in particular, a significant proportion of consumption expenditure is spent on housing and energy, even minor changes to their relative weighting as part of the total consumption will affect emissions. The technological change reduced emissions by 6,683 Mkg CO_2e. The emission coefficients decreased for almost all commodities. The greatest changes once again occurred in *housing, energy* and *fuel and lubricants*. Among other things, the change towards lower emissions in electricity and heat production extensively affects the emissions from commodity production chains and thus the carbon footprint of households. Only the emission coefficients for *passenger transport by sea* and *tourism expenditures abroad* increased slightly.

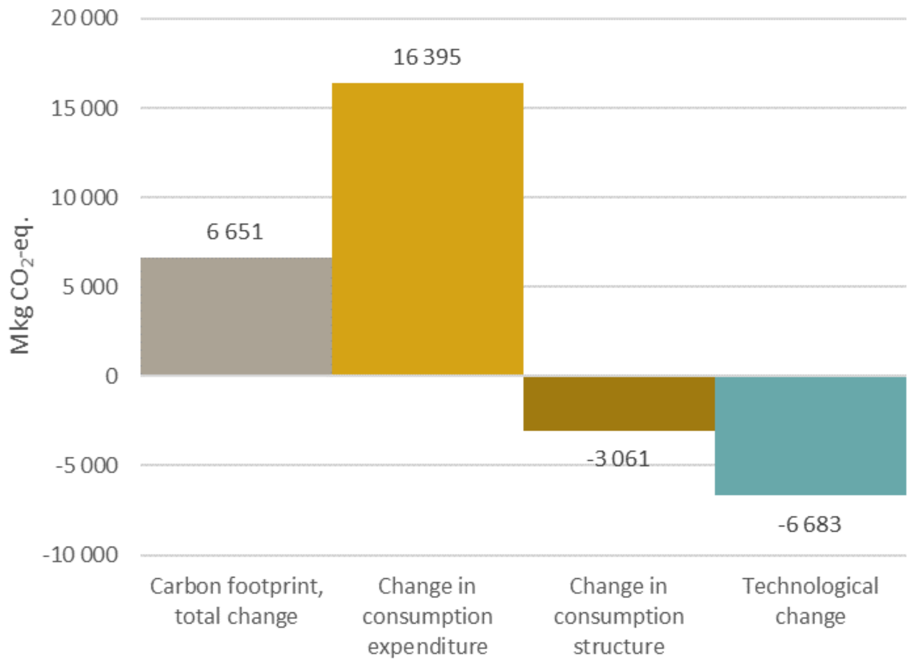

Figure 12. Total change in carbon footprint and effects of changes in expenditure, structure and technology in 2000–2016.

The change in consumption expenditure was a key element behind the increased carbon footprint. The reduction in emission coefficients, or technological change, was the most important factor reducing the carbon footprint, and the change in the consumption structure also reduced greenhouse gas emissions. However, these were not sufficient to compensate for the increase in emissions caused by increasing consumption, which is why the carbon footprint of household consumption has increased overall between 2000 and 2016. Hoektra and Van Den Bergh (2002) examined more than 27 studies using the structural decomposition method to assess the environmental impacts of the economy. In terms of three components, the results were similar to those obtained in this study.

The change in the carbon footprint of household consumption can also be examined by commodity group. In Figure 13, the change in emissions for each commodity group between 2000 and 2016 has been decomposed into three components. In the figure, the components of each group are summed up in the overall change in the carbon footprint, and the components are summed up across the commodity groups in the overall changes shown in Figure 12. In *food and non-alcoholic beverages*, higher consumption expenditure increased emissions. The change in the consumption structure and the technological development reduced the carbon footprint slightly, but they were not able to compensate for the impact of the increase in consumption expenditure. In *housing and energy*, the technological change reduced emissions so strongly that overall, the carbon footprint of the commodities group decreased. As the *furnishings, household equipment and services* form only a small proportion of the whole within the group, the impact of the change in the consumption structure remained very small. In *transport*, the change in the consumption structure reduced emissions more than the technological change. Within the group, the share of *fuel and lubricants* in consumption decreased. As the commodity in question has plenty of weight within the group and a high emission coefficient, the emission-reducing effect of the change in the consumption structure is explained mainly by this factor. However, the change in consumption expenditure led to an increase in the carbon footprint of the commodity group. In *other goods and services*, the technological change reduced emissions only slightly, while the change in consumption expenditure and the change in the consumption structure increased the carbon footprint.

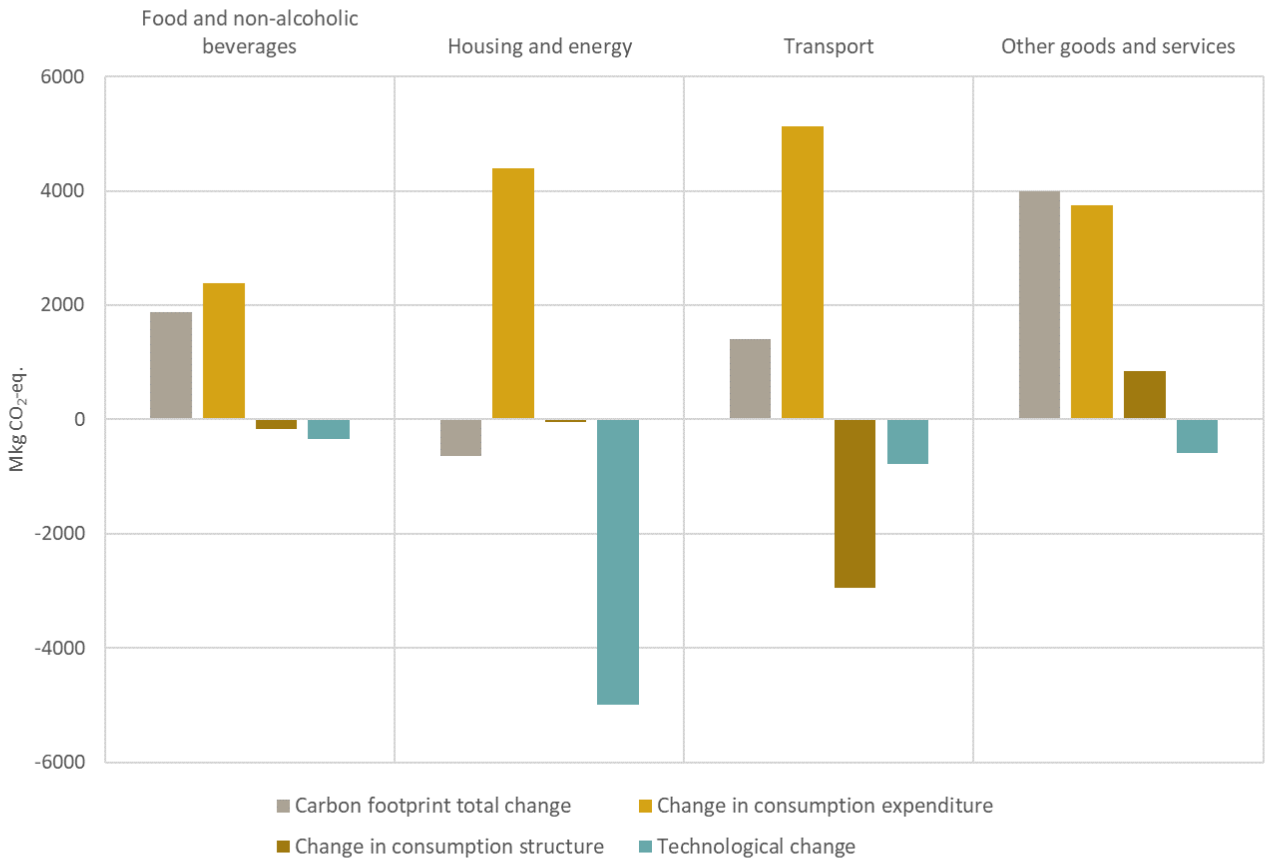

Figure 13. Change in carbon footprint by main commodity categories in 2000–2016.

The structural decomposition analysis can also be used to examine consecutive years. An assessment of a set of two years reveals changes that have had impacts in opposite directions and which cannot be observed by decomposing the development between the start and the end year. Figure 14 shows the results of the SDA of sets of two years. In the figure, the elements of each set of two years are summed up in the overall change, and each of the four variables is summed up in the overall changes in Figure 12. The overall change in the carbon footprint has varied considerably over the period considered: between 2005 and 2006, the carbon footprint increased by approximately 5,500 Mkg CO_2e, and between 2011 and 2012, the carbon footprint decreased by approximately 5,780 Mkg CO_2e. The impact of the change in consumption expenditure on the carbon footprint strongly followed the development of GDP: the financial crisis and the resulting recession decreased consumption in 2009 and 2013, and as a result, the increase in emissions was less prominent than in previous years.

The change in the consumption structure has mainly reduced the carbon footprint over the period examined, and the change in the consumption structure has increased the carbon footprint of households only in 2008–2009, 2009–2010 and 2012–2013. Thus, during an economic recession, consumption has been directed at commodities whose emission coefficients are relatively higher. In particular, between 2008 and 2009, the impact of the change in the consumption structure was significant (over 1,000 Mkg CO_2e). Since at the same time, consumption expenditure decreased as a whole, the total change in the carbon footprint was negative, i.e. the emissions decreased.

At the beginning of the studied period, technological change increased the carbon footprint during some sets of years. Since 2006, the reduction in emission coefficients has reduced emissions, with the exception of the period between 2008 and 2009 (increase by 112 Mkg CO2e), 2009–2010 (936 Mkg CO2e), 2012–2013 (514 Mkg CO2e) and 2015–2016 (4,144 Mkg CO2e). 2010 was exceptionally cold, and 2015 was exceptionally warm. The need for heating and the amounts of fossil fuels used in these years are particularly strongly reflected in the fact that technological change increased the carbon footprint in 2009–2010 and 2015–2016. Between 2011 and 2012, the technological change significantly reduced emissions. The main reason for this was the reduction in the GHG emissions of both domestic and imported electricity.

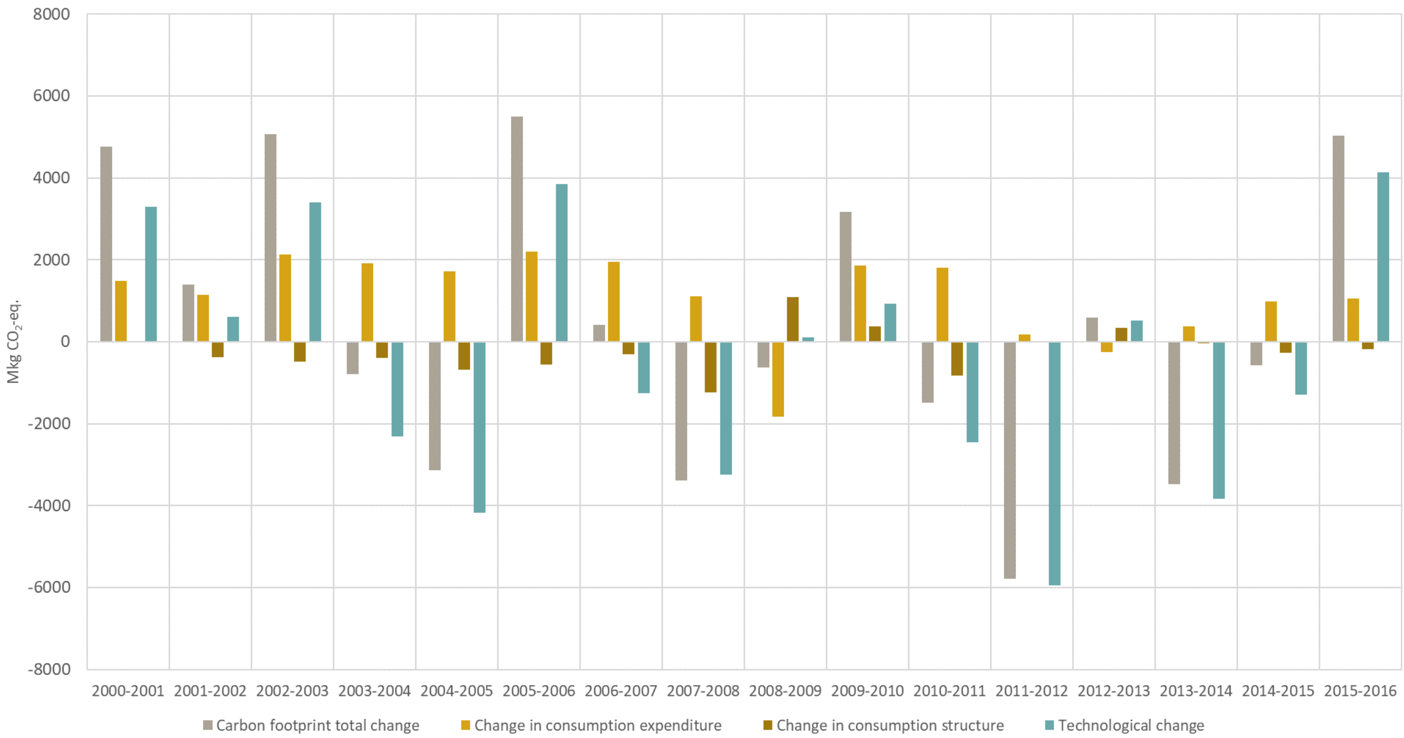

Figure 14. Total change in carbon footprint and effects of changes in expenditure, structure and technology in years 2000–2016.

3.3.3 Use of raw materials for household consumption in 2015

In 2015, the use of raw materials (RMR) due to household consumption[6] was 64,800 million kg (i.e. 64.8 million tonnes, Mt). Of this, the share of *other goods and services* was 32%, the share of *housing and energy* 30%, the share of *foods and non-alcoholic beverages* 26% and the share of *transport* 12%. Of the total consumption expenditure (EUR 110,362 million), the corresponding shares were 44%, 33%, 13% and 11%. The RMR coefficient for *other goods and services* was clearly lower than, for example, that of *foods and non-alcoholic beverages*.

The average use of raw materials in Finland followed the share of consumption expenditure in 2015 (Table 7). *Housing and energy* constituted the largest commodity group, in terms of both consumption expenditure and the use of raw materials. *Plant-based and animal-based food items* each accounted for 13% of raw material use. The next largest groups were *recreation and culture*, the *use of private vehicles* and *furnishing, household equipment and services*.

[6] No time series material similar to that available for the carbon footprint is available in connection with the use of raw materials. For this reason, only a single year has been analysed.

Table 7. Average consumption expenditure and raw material requirement (RMR) by commodity groups in 2015.

	Consumption expenditure 2015	Share	RMR per capita in 2015	Share
Commodity group	euroa	%	kg	%
Plant-based food items	1 503	7%	1 532	13%
Animal-based food items	1 113	6%	1 547	13%
Alcoholic beverages and tobacco	894	4%	229	2%
Clothing and footwear	812	4%	273	2%
Housing and energy	5 616	28%	2 548	22%
Furnishing, household equipment and services	986	5%	970	8%
Health	883	4%	253	2%
Purchase of vehicles	610	3%	206	2%
Operation of personal transport equipment	1 289	6%	1 028	9%
Transport services	405	2%	237	2%
Communication	459	2%	145	1%
Recreation and culture	2 059	10%	1 386	12%
Education	79	0%	16	0%
Restaurants and hotels	1 120	6%	486	4%
Other goods and services	1 963	10%	627	5%
Tourism expenditure abroad	574	3%	335	3%
Total	20 141	100%	11 818	100%

The consumption expenditure of households, the carbon footprint and the use of raw materials in 2015 have been compared in Figure 15. The magnitudes of the loads are clearly different in some commodity groups. The carbon footprint is considerably larger than the use of raw materials in the *use of private vehicles*.[7] The main reason is the direct carbon dioxide emissions from transport fuels. The use of raw materials in the production chains of commodities is clearly higher than greenhouse gas emissions in *plant-based food items* and in several groups containing services. The consumption of *other goods and services and healthcare* causes the relatively lowest environmental load when examining the carbon footprint and the use of raw materials.

The link between material flows caused by household consumption and greenhouse gas emissions has been examined on the level of 59 commodities in Figure 16. The use of raw materials is described for each commodity on the horizontal axis, and the carbon footprint is described on the vertical axis.

The figure indicates that GHG strongly correlates with the RMR. The material contains two outliers. The greenhouse gas emissions of fuel and lubricants (RMR = 4,200, GHG = 13,800) are more than three times higher than those of raw material use. This is a very different kind of commodity compared to others. Both loads are considerably high in housing (RMR = 14,000, GHG = 12,000). The reason for this is the considerable amount of expenditure for the commodity group. These two observations are well on the same regression line as the main group of observations, but since it is clearly an abnormal finding, it was ignored in the calculation of the degree of explanation. The degree of explanation of the connection between the variables is very high (R2 = 0.89).

[7]The construction and maintenance of road infrastructure that enables the use of private vehicles is highly raw material intensive. However, this is not reflected in the lifecycle use of raw materials for commodities, as road construction is recorded in investments, not in consumption.

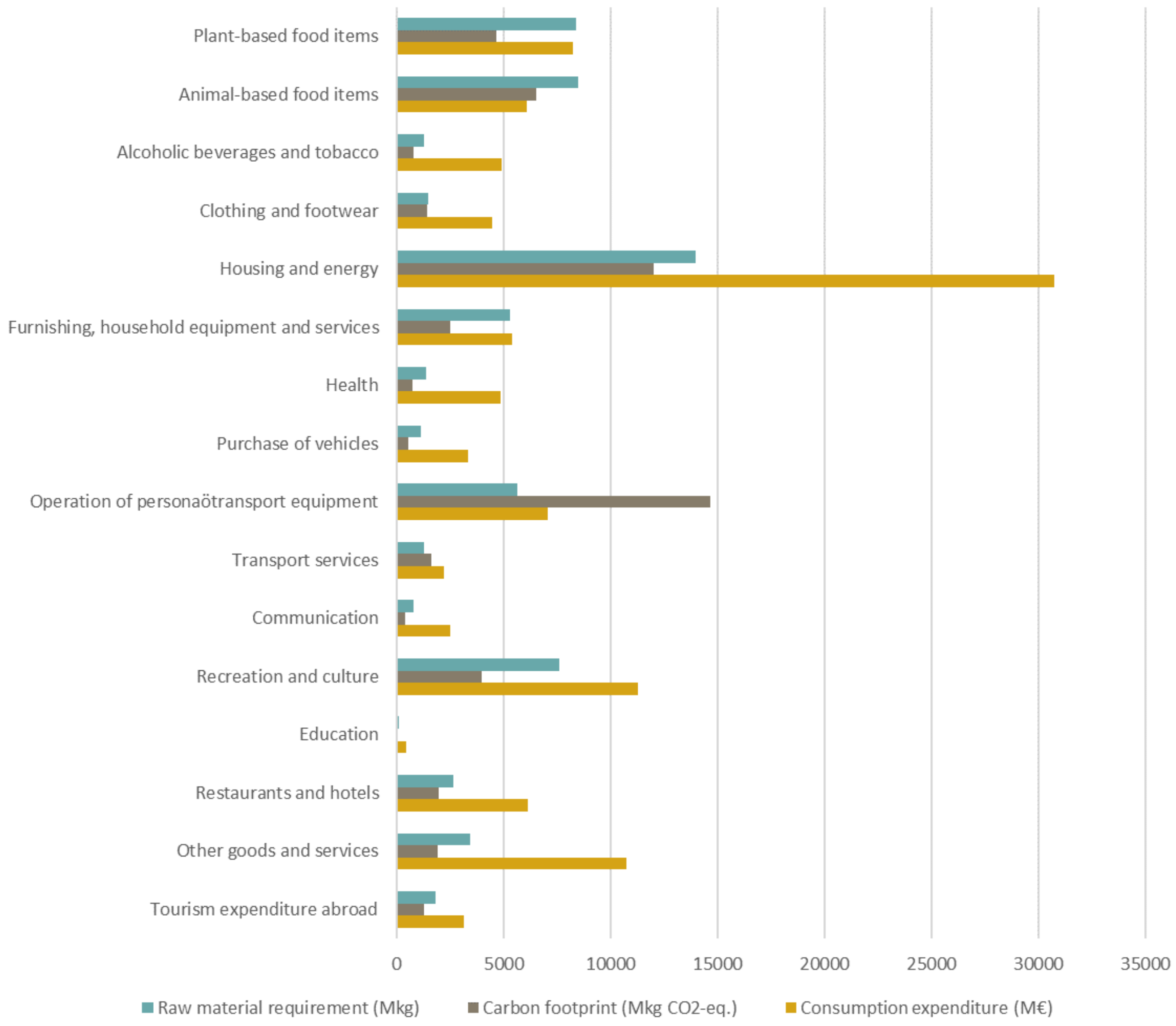

Figure 15. Household consumption expenditure, carbon footprint and raw material requirement in 2015 by commodity groups.

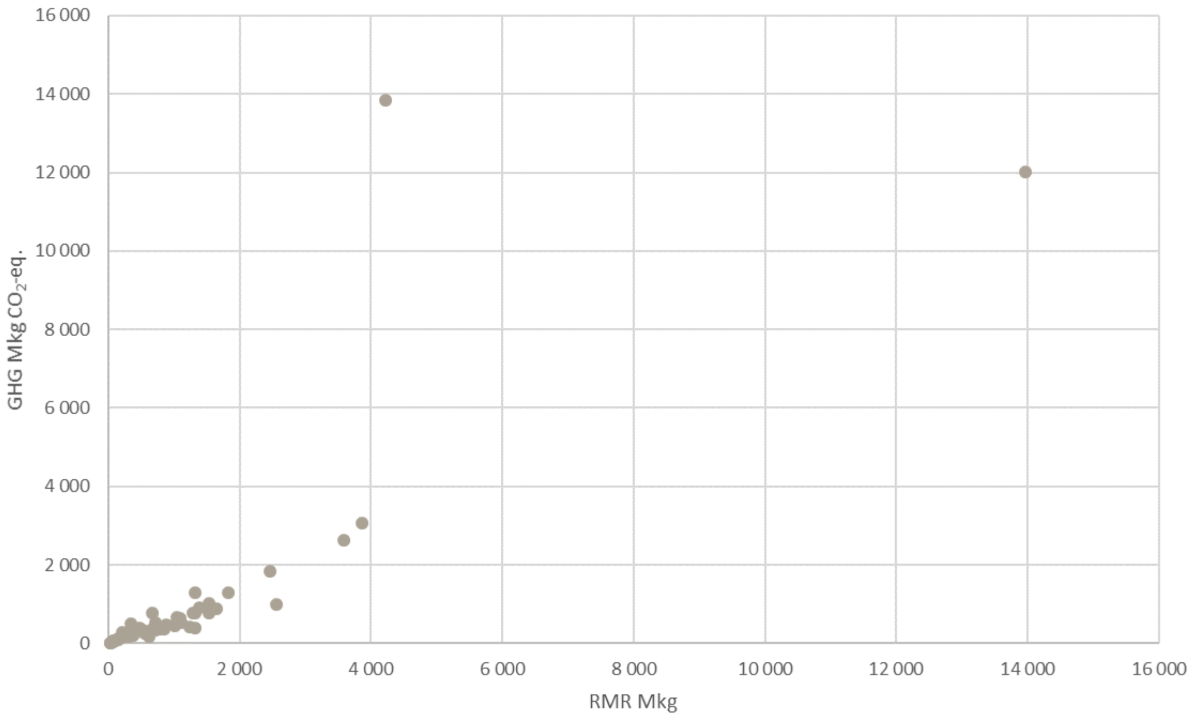

Figure 16. Correlation between raw material requirement (RMR) and greenhouse gas emissions (GHG) in data with 59 commodity groups.

3.4 Carbon footprints of households with different characteristics

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3.4.1 Consumption expenditure of households and their carbon footprint in 2016

The carbon footprint of household consumption expenditure for 2000–2016 was presented in the previous Chapter 3.3. The carbon footprint of household consumption expenditure can also be examined using Statistics Finland's Household Budget Survey (HSB). The data collected for each household in the HSB make it possible to examine the consumption of different types of households. This chapter examines the carbon footprint in relation to the income level, the life phase (number of people and age group) and the urban or rural category of the place of residence.

Table 8 presents an overview of Finnish household consumption expenditure and carbon footprint based on the 2016 HSB (Statistics Finland 2018). The consumption expenditure correspond to the 2016 fair value. The table shows the total emissions and emissions per person and per consumption unit. This chapter examines consumption as calculated per unit of consumption. The calculation method based on consumption units takes the economies of scale into account per person more effectively than per capita values. The economy of scale means that consumption does not increase in a straightforward manner for each additional person in the household (Nurmela 2008). For example, there is little need for more household appliances, even if the number of people in the household increases. This report makes use of the OECD definition contained in Statistics Finland's material and currently recommended by Statistics Finland. In this case, the consumption units are formed as follows (Statistics Finland 2018, p. 26): “The weighting of the first adult in a household is 1.0, the weighting of the next members of the household aged 14 or over is 0.5, and the weighting of children under 14 years of age is 0.3.”

Table 8. Household consumption expenditure and derived carbon footprints based on Household budget survey 2016.

Commodity group	Mkg CO_2e	Kg CO_2e per capita	Kg CO_2e per consumption unit	Share of emissions	Consumption expenditure M€	Share of conumption expenditure	GHG intensity kg CO_2e per €
Food and non-alcoholic beverages	8 901	1 643	2 296	19%	11 729	12%	0.76
Housing and energy	15 753	2 907	4 064	33%	30 736	32%	0.51
Furnishing, household equipment and services	1 906	352	492	4%	4 270	4%	0.45
Transport	12 578	2 321	3 245	27%	15 549	16%	0.81
Other goods and services	8 051	1 486	2 077	17%	33 893	35%	0.24
Total	47 189	8 709	12 173	100%	96 177	100%	0.49

Table 8 indicates that housing represents the largest single source of emissions, 37% of the carbon footprint, when adding up the energy consumption of housing and household furniture, machinery, goods and services (i.e. COICOP categories 04 and 05). Other goods and services cause 17% (including COICOP categories 02, 03, 06, 08, 09, 10, 11 and 12), transport causes 27% (COICOP category 07), and food (COICOP category 01) causes 19% of emissions. However, it is noteworthy that package travels are included in the Other goods and services category. With regard to food, it is noteworthy that restaurant services are also included in the services category. The consumption expenditure of the consumption survey in Table 8 do not include items outside consumption expenditure, for example tax-like payments and interests on loans.

The emission intensity, i.e. the ‘carbon footprint of the euro spent’ (whose unit is kg CO_2e / €) varies by category of consumption expenditure (Table 8). The highest emission intensity is that of transport, which is explained by the emissions generated by the combustion of fossil fuels and the relatively low fuel price compared to the emissions generated. Food also has a high emission intensity. The two categories of housing / the home have clearly lower emission intensities, and the other goods and services have the lowest carbon footprint per euro spent. The average carbon footprint of the euro is 0.49, i.e. approximately half a kilogram of greenhouse gas emissions per euro spent.

The data in the national accounts and the consumption expenditure survey on household consumption expenditure are different (Table 9). For more information on the differences between the methods and limitations of data collection, see Chapter 2.3. In national accounts, household consumption expenditure are EUR 16.3 million higher than the expenditure based on consumption survey data. In addition, the distribution of consumption expenditure differs so that the consumption expenditure of *food, furnishing, household equipment and services, and other goods and services* in the national accounts are higher than the information obtained from the consumption expenditure survey. *Housing and energy* expenditure are close to each other in the data, and *transport expenditure* are higher in the consumption expenditure survey than they are in national accounts. Thus, the most suitable data should be selected according to the intended use. National accounts provide a comprehensive overview of household consumption expenditure on the national level. On the other hand, the background data of the HBS enables research on the consumption expenditure and carbon footprints of different types of households.

Table 9. Household consumption expenditure and carbon footprint in 2016. Comparison of national accounts and household budget survey.

	National accounts 2016				Household budget survey 2016			
Commodity group	**Cons. exp. M€**	**Share of cons. exp.**	**Mkg CO_2e**	**Share of emissions**	**Cons. exp. M€**	**Share of cons. exp.**	**Mkg CO_2e**	**Share of emissions**
Food and non-alcoholic beverages	14 382	13%	11 433	19%	11 729	12%	8 901	19%
Housing and energy	31 158	27%	14 637	24%	30 736	32%	15 753	33%
Furnishing, household equipment and services	5 468	5%	2 576	4%	4 270	4%	1 906	4%
Transport	13 353	12%	18 204	30%	15 549	16%	12 578	27%
Other goods and services	49 294	43%	13 238	22%	33 893	35%	8 051	17%
Total	**112 432***	**100 %**	**60 088**	**100%**	**96 177**	**100 %**	**47 189**	**100%**

*) Expenditure from national accounts 2016 are in 2015 prices.

3.4.2 Carbon footprint of household consumption expenditure by income level

The income level is linked to the volume and quality of consumption and the carbon footprint of consumption expenditure. Households can be divided by income into categories of a similar size, such as deciles (Table 10). The table has been compiled based on the variable in Statistics Finland's data, in which deciles are formed by dividing households by ten per unit of household consumption according to the disposable income. Due to sample formation, the number of households is not exactly the same in different deciles (Table 11).

Table 10 and the figure show the carbon footprint of consumption expenditure per consumption unit. As can be assumed, the carbon footprint increases as income increases, since consumption expenditure typically increase as income increases. In the calculation of emissions, each euro spent on a particular consumption product group increases emissions equally. According to a Swiss study (Girod and De Haan 2010), wealthy consumer groups may pay a higher price for products and services. In other words, the amount of consumption in terms of products does not necessarily grow in the same proportion as the euros spent. However, the conclusions of the study stated that consumption is not only directed at more expensive products and services, but the amount consumed also increases as consumption expenditure increase.

When examining the differences between the carbon footprints of the lowest and highest decile, it is observed that the carbon footprint of *food* consumption and *housing* in the highest class is twice that of the lowest class. The relative increase in the carbon footprint of *transport* and *other goods and services* is greater. *Transport* emissions almost quadrupled and the consumption of *other goods and services* will more than triple when comparing the lowest and highest income categories. Relative differences may be explained by the necessity of *food* consumption (everyone needs to eat but it is not meaningful to consume many times more food) and the fact that *housing* differences are balanced out by social security.

When examining the share of the areas of consumption in the carbon footprint, the three smallest income deciles stand out from the upper ones for *housing* and *transport*: The share of *housing* in the carbon footprint is 42–46% in the lowest three deciles and 35–37% of the carbon footprint in the higher deciles. As for *transport*, it produces 18–22% of the carbon footprint of the three lowest deciles and 27–

29% in the upper deciles. The share of *food* ranges from 19–22% in deciles 1–8, and it is 16–17% in deciles 9 and 10. The proportion of *other goods and services* varies between 15% and 20%.

Nurmela (2018) examined the changes in consumption by income category between 1985 and 2016. According to him, consumption has become more similar during the period examined, in the sense that the proportions of consumption expenditure are fairly similar in different income groups.

Table 10. Carbon footprint of household expenditure per consumption unit by income deciles in 2016.

Income decile	Carbon footprint kg CO_2e per consumption unit					Emission intensity kg CO_2e per €	
	Food	Other goods and services	Transport	Housing	Average carbon footprint	Total expenditure	Expenditure excluding housing
1	1 413	1 200	1 471	3 154	7 238	0.50	0.48
2	1 643	1 212	1 454	3 687	7 996	0.51	0.47
3	1 978	1 358	1 971	3 770	9 077	0.52	0.49
4	2 225	1 699	2 912	3 919	10 755	0.51	0.51
5	2 310	1 783	3 216	4 213	11 522	0.50	0.50
6	2 401	1 918	3 223	4 516	12 057	0.52	0.52
7	2 513	2 257	3 476	4 714	12 960	0.49	0.48
8	2 596	2 328	3 946	4 792	13 663	0.49	0.50
9	2 539	2 790	4 295	5 472	15 097	0.47	0.47
10	2 962	3 743	5 553	6 692	18 950	0.46	0.45
Average, all households	**2 296**	**2 077**	**3 245**	**4 556**	**12 173**	**0.49**	**0.48**

The carbon footprint of consumption expenditure per euro spent (Table 10) varies little between the deciles. This suggests, as has previously been mentioned, that the consumption structure is fairly uniform regardless of the income level. Table 10 indicates the carbon footprint for consumption per euro spent, for consumption in total and for consumption excluding housing. This was done so that the results may also be presented in a coherent manner in conjunction with a comparison between places of residence in cities and in the countryside (Table 14).

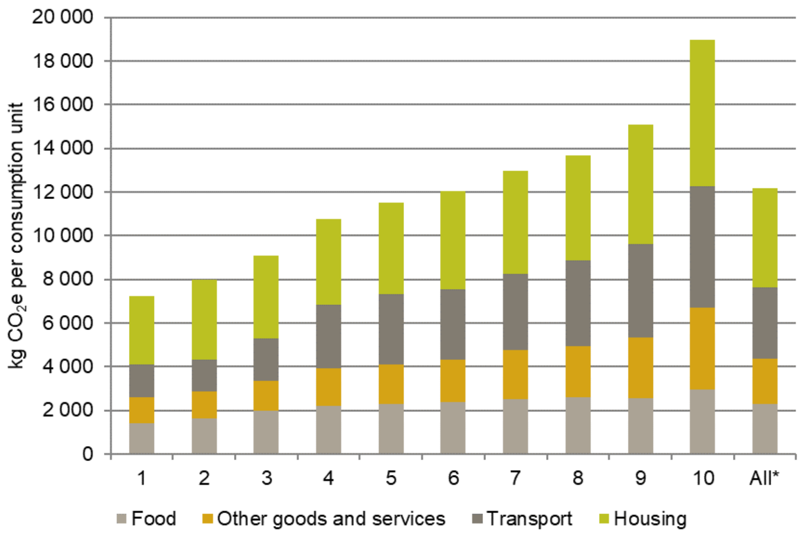

Figure 17. Carbon footprint of household consumption expenditure per consumption unit by income deciles based on household budget survey 2016. *Average from all households.

Background information on households within the income deciles has been compiled in Table 11. In Table 11 and subsequently in similar tables, the column indicating the number of observations refers to the number of households interviewed in Statistics Finland's survey. In low-income households, the average number of persons and consumption units is lower than in higher-income deciles. As household income increases, the surface area of the dwelling also increases. However, the surface area calculated per consumption unit increases less than the total surface area. According to the consumer survey data, the average area of household dwellings was 90 m^2 in 2016. According to Statistics Finland's housing and living conditions statistics, the surface area per group of inhabitants residing in the same dwelling was 81.7 m^2 in 2016. The differences are likely to be influenced by the way the data is collected. In the consumption survey, the respondents themselves report the surface area of their home, in which case those living in detached houses have been found to report a larger surface area compared to the cadastral register (Statistics Finland 2018). Here, income shall refer to monetary income (Statistics Finland 2019a).

Table 11. Descriptive data on households by income deciles in 2016.

Income decile	Number of households		Average by income decile				
	Observations in sample	Households in decile	Persons per household	Consumption units per household	Living space m^2	Living space m^2 per consumption unit	Income per consumption unit €
1	260	268 384	1.3	1.1	46	41	11 110
2	260	267 168	1.7	1.3	60	47	15 033
3	315	268 002	1.9	1.4	67	49	17 806
4	338	268 298	2.3	1.5	86	56	19 695
5	358	267 038	2.2	1.5	90	60	22 081
6	376	267 628	2.2	1.5	92	61	24 628
7	397	267 563	2.2	1.5	98	63	27 473
8	444	267 612	2.2	1.5	109	71	30 557
9	454	268 025	2.2	1.5	118	78	35 972
10	471	267 381	2.2	1.6	137	88	57 072
All households, total or average	3 673	2 677 100	2.0	1.4	90	62	26 902

3.4.3 Carbon footprint of household consumption expenditure by household type

In this context, the type of household refers to the characteristics related to the number of persons in the household and the phase of their life. The number of working age adults and dependants in household affect the disposable income, both in its entirety and per consumption unit. The phase of life may also affect the structure of consumption, i.e. what kind of goods and services are consumed. Table 12 and Figure 18 present the carbon footprint of consumption expenditure by household type. The largest carbon footprint per consumption unit is found in households of couples withour children. If the household has two earners, but no dependent children, more income calculated per person and consumption unit (Table 13) is available than in households with dependent children or a single earner. Although the number of recipients of income has not been taken into account in the household types listed in Table 12, it is clear that, for example, a family with children and two guardians more often has two recipients of income than single-parent households.

Table 12. Household carbon footprint from consumption expenditure by type of households in 2016.

Type of household	Carbon footprint kg CO_2e per consumption unit					Emission intensity kg CO_2e per €	
	Food	Other goods and services	Transport	Housing	Total carbon footprint	Total expenditure	Expenditure excluding housing
Single (below 65 yrs)	1 782	1 944	2 777	4 690	11 192	0.49	0.47
A couple, no children living at home (both below 65 yrs)	2 517	2 686	4 491	4 955	14 649	0.49	0.48
A parent with a child or children	1 912	1 805	2 275	4 372	10 364	0.49	0.47
A couple with a child or children	2 573	2 322	3 743	3 902	12 539	0.49	0.50
Household with at least one person above 64 yrs	2 197	1 496	2 083	5 186	10 962	0.49	0.46
Other	2 503	2 070	3 748	3 995	12 316	0.49	0.51
Average, all households	2 296	2 077	3 245	4 556	12 173	0.49	0.48

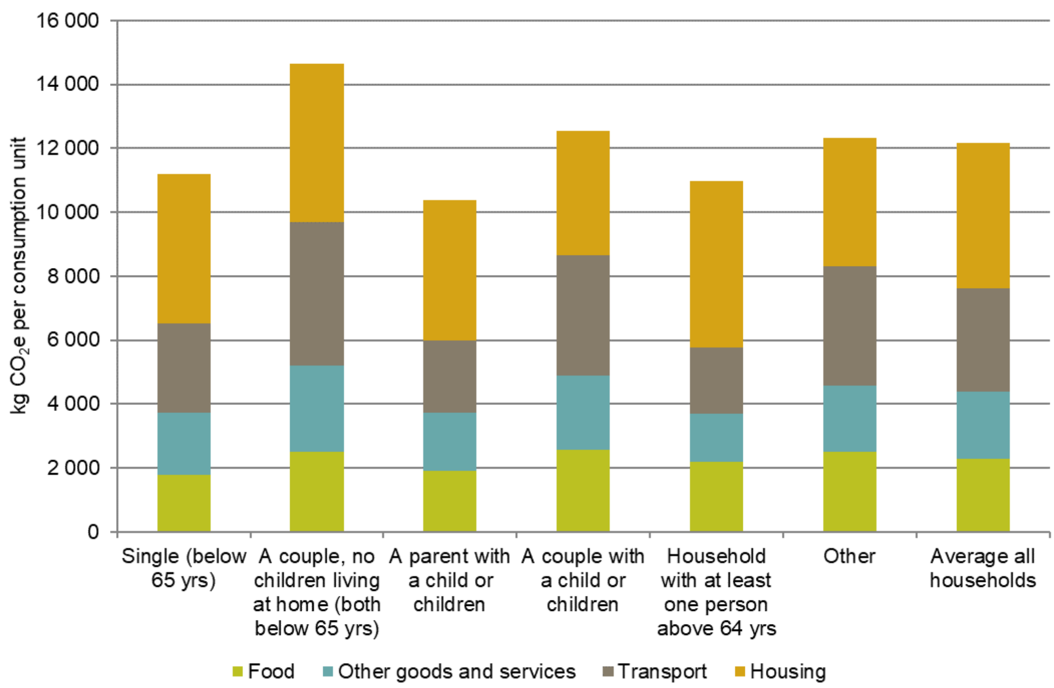

Figure 18. Carbon footprint of household consumption expenditure by type of household in 2016.

The carbon footprint of housing per consumption unit is the highest in households of over-64-year-olds (Table 12). These households also have the largest living area per unit of consumption (Table 13). This is probably explained by the fact that some households with residents over the age of 64 live in the same dwelling where their children previously lived. The highest transport emissions calculated per unit of consumption are exhibited by couples without children and the second-largest by families with two guardians (Table 12). It is likely that the active phase of life and disposable income affect their travel needs and opportunities. The carbon footprints for food and other goods and services calculated per unit of consumption are also largest for couples without children and families with two guardians.

Table 13. Descriptive data on household by household types in 2016.

		Averages by household types					
Household type	**Observations in sample**	**House-holds**	**Consumption units per household**	**Living space m²**	**Living space m2 per consump-tion unit**	**Income per consumption unit €**
Single (below 65 yrs)	723	699 558	1.0	56	56	21 574
A couple, no chil-dren living at home (both below 65 yrs)	747	446 409	1.5	96	64	34 533
A parent with a child or children	108	107 565	1.6	89	54	20 900
A couple with a child or children	735	475 979	2.2	128	57	28 620
Household with at least one person above 64 yrs	1 008	752 274	1.2	87	72	23 086
Other	352	195 314	1.9	121	65	30 451
Average, all households	3 673	2 677 100	1.4	90	62	26 902

3.4.4 Carbon footprint of household consumption expenditure by urban / rural category of residence

Several studies have sought to establish the link between the carbon footprint of consumption and the urban/rural typology of place of residence (e.g. Ala-Mantila et al. 2016; Gill and Moeller 2018; Ivanova et al., 2017; Minx et al. 2013). The conclusions of the studies are not unambiguous. However, research has revealed that transport emissions are often smaller for people living in urban dense community structures than for those living in outer urban areas. The carbon footprint of people living in densely populated areas, typically in city centres, is increased by the consumption of goods and services. There are plenty of consumption opportunities in urban centres, and on the other hand, housing is often expensive, which means that living in these areas may require a high income.

The background information for the consumption expenditure material includes the urban or rural category of the household. There are seven classes in total (Table 14). The Finnish classification (Helminen et al. 2014) is based on spatial data, not e.g. on administrative classifications, such as municipal boundaries. The classification is detailed, which means that it is mainly based on a grid of 250 x 250 metres. Data sources include data on the population, the distribution of the industry of employed persons, commute and construction data, as well as the DIGIROAD road network data and the CORINE land use data. Figure 19 shows Finland's map for the urban-rural classification.

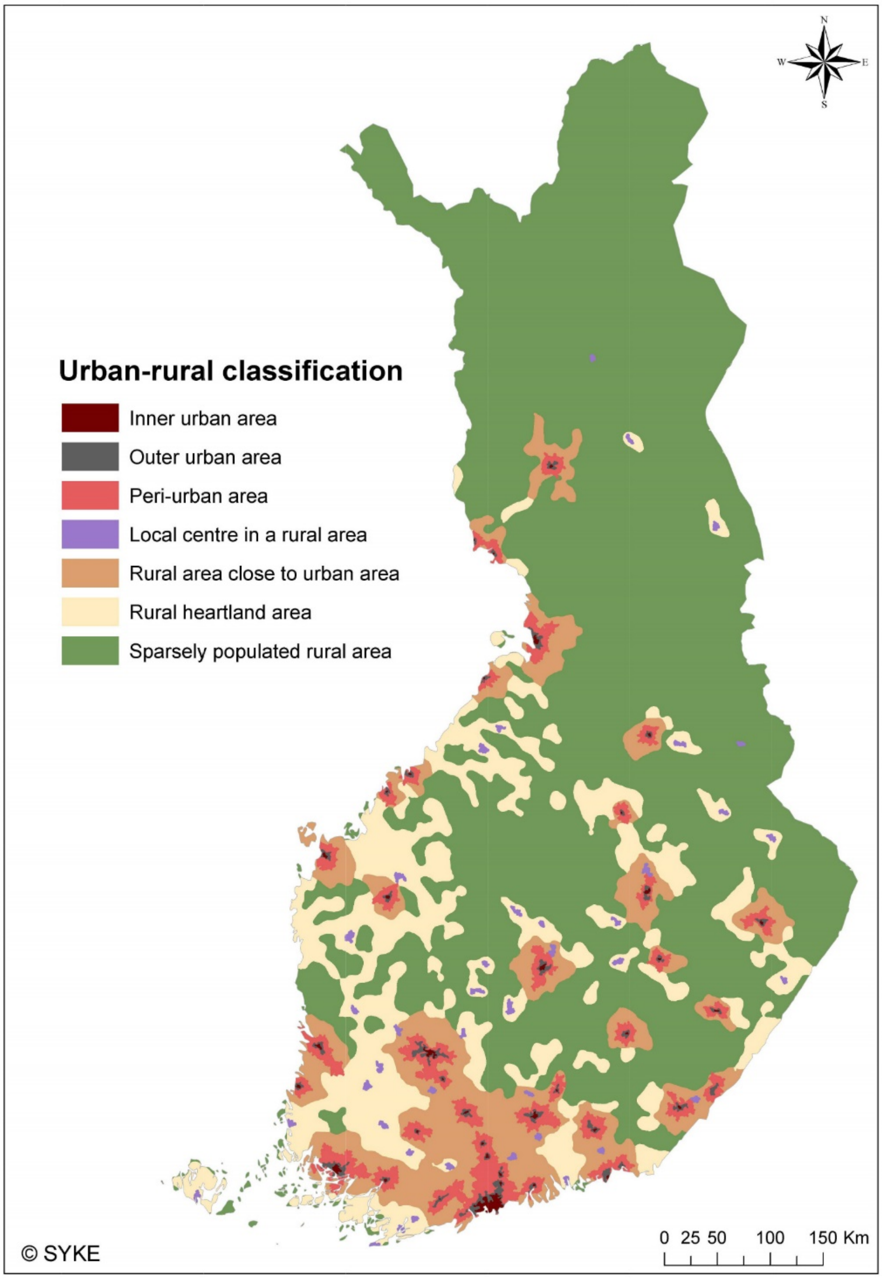

Figure 19. Urban-rural classification in Finland. Source: https://www.ymparisto.fi/kaupunkimaaseutuluokitus

Table 14 and Figure 20 indicate the carbon footprint of household consumption expenditure (including *food, other goods and services, transport*) by household category. The carbon footprint has not been calculated for housing. Housing differs from other consumption expenditure categories in that the price of housing, especially rents and calculated rents specified for owner-occupied housing, varies greatly depending on the place of residence, both in different parts of the country and in urban and rural categories. In this study, the calculation of the carbon footprint is based on the euros spent. As described in Chapter 2, emission coefficients have been calculated to produce results that match the consumption expenditure of households at the national level. In urban and rural classes, carbon footprint calculations based on the price of housing would overestimate the emissions of housing in costly housing areas and, similarly, underestimate them where the price of housing is affordable. The calculation method would also not take into account regional differences in the emission intensity of energy production. For the reasons mentioned above, the carbon footprint of housing is not presented for the categories of the area of residence.

Table 14. Carbon footprint of household consumption expenditure by place of residence in 2016.

Place of residence	Carbon footprint kg CO_2e per consumption unit				Emission intensity kg CO_2e per €
	Food	Other goods and service	Transport	Total excl. housing	Expenditure excl. houshing
Inner urban area	2 178	2 322	2 414	6 913	0.43
Outer urban area	2 322	2 170	3 388	7 880	0.48
Peri-urban area	2 397	2 136	3 952	8 485	0.51
Local centre in a rural area	2 185	1 871	3 225	7 281	0.48
Rural area close to urban area	2 438	1 804	4 193	8 436	0.54
Rural heartland area	2 378	1 712	3 568	7 658	0.54
Sparsely populated rural area	2 428	1 474	4 081	7 983	0.56
Average all households	2 296	2 077	3 245	7 618	0.48

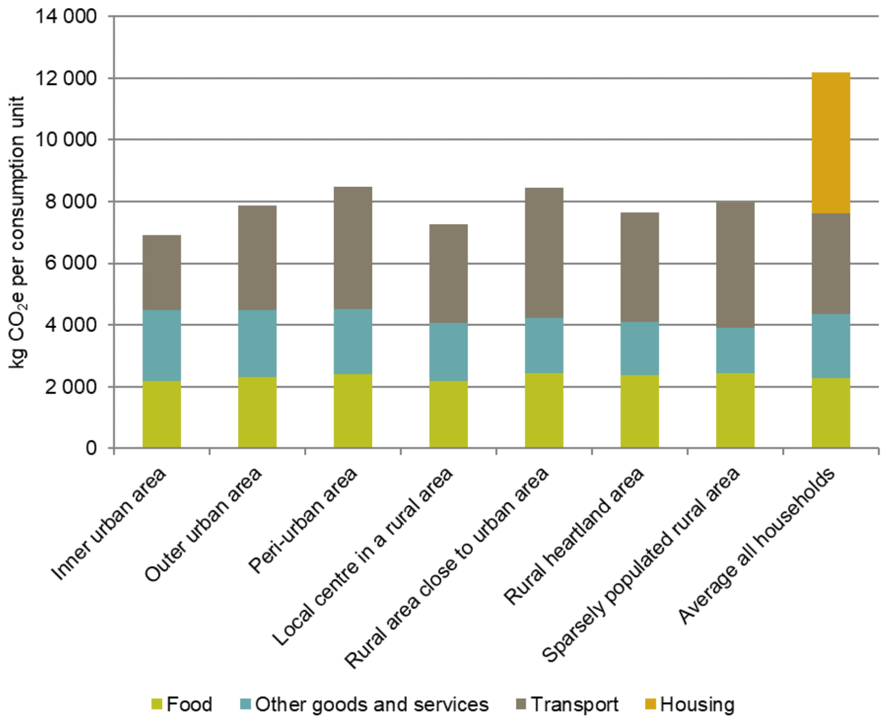

Figure 20. Carbon footprint of household expenditure per consumption unit in 2016. Housing carbon footprint is shown only for the average households due to methodological issues.

The carbon footprints calculated from the HBS (Table 14 and Figure 20) indicate that there is no great variation in the carbon footprint of food consumption between urban rural categories. The largest differences between the categories lie in transport. The carbon footprint of transport is at its greatest in rural areas close to the city, and the second-largest footprint is found in sparsely populated rural areas and the peri-urban areas. The smallest transport carbon footprint is found in the inner urban area. The differences are probably explained by the daily travelling distances and the modes of transport available.

The modes of transport also include personal vehicles. In the inner urban area, the share of car-owning households is 54%, and in the outer urban areas, the share of car-owning households is 83%.

The number of households without cars was small in areas surrounding cities and in rural areas. When the share of car-owning households is calculated for all rural categories, it is 83%.

The 'Other goods and services' category has the largest carbon footprint in the inner urban area, followed by the outer urban area and the areas surrounding cities.

Background information on households has been compiled in Table 15 according to the area of residence. 70% of households are located in urban areas. These households comprise 3.7 million people, or 69% of the study population. The smallest households, based on the number of persons and consumption units, are located in the inner urban area and in rural centres. The largest households are located in the peri-urban areas. Rural areas close to the city have the largest living surface area per consumption unit.

Table 15. Descriptive figures on households by place of residence in 2016.

			Averages by urban-rural classification				
Place of residence	**Observations in sample**	**House-holds**	**Persons in house-hold**	**Consumption units in household**	**Living space m^2**	**Living space m^2 per consumption unit**	**Income per consumption unit €**
Inner urban area	1 104	935 736	1.8	1.3	69	51	27 462
Outer urban area	894	665 531	2.1	1.5	91	61	28 631
Peri-urban area	364	260 904	2.5	1.6	111	68	26 867
Local centre in a rural area	294	174 766	1.9	1.4	93	67	24 818
Rural area close to urban area	266	189 578	2.3	1.6	119	76	25 311
Rural heartland area	527	312 926	2.1	1.5	107	72	25 101
Sparsely populated area	224	137 658	2.1	1.5	110	74	24 044
All households, total or average	3 673	2 677 100	2.0	1.4	90	62	26 902

4 Discussion and conclusions about the carbon footprint of public and household consumption

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4.1 Comparisons with other studies

Household consumption causes multiple greenhouse gas emissions compared to public consumption and investments

Households and the public sector are not highlighted in Finland's official greenhouse gas emissions, but the situation changes completely when the emissions are analysed from a consumption-based viewpoint, i.e. considering what the goods and services produced are ultimately used for (Figure 21). The share of investments (mainly construction, the majority of which is carried out by the private sector) was less than 20% of emissions (19.3%). Household consumption caused 66% and public consumption 12% of emissions.

While two methods of calculating consumption emissions produced slightly different results, this does not change the overview of the sources of emissions: Household consumption plays an extremely important role in Finland's emissions. Emissions from household consumption are more than five times higher than emissions from the public sector and public procurement, and more than three times higher than emissions from investments.

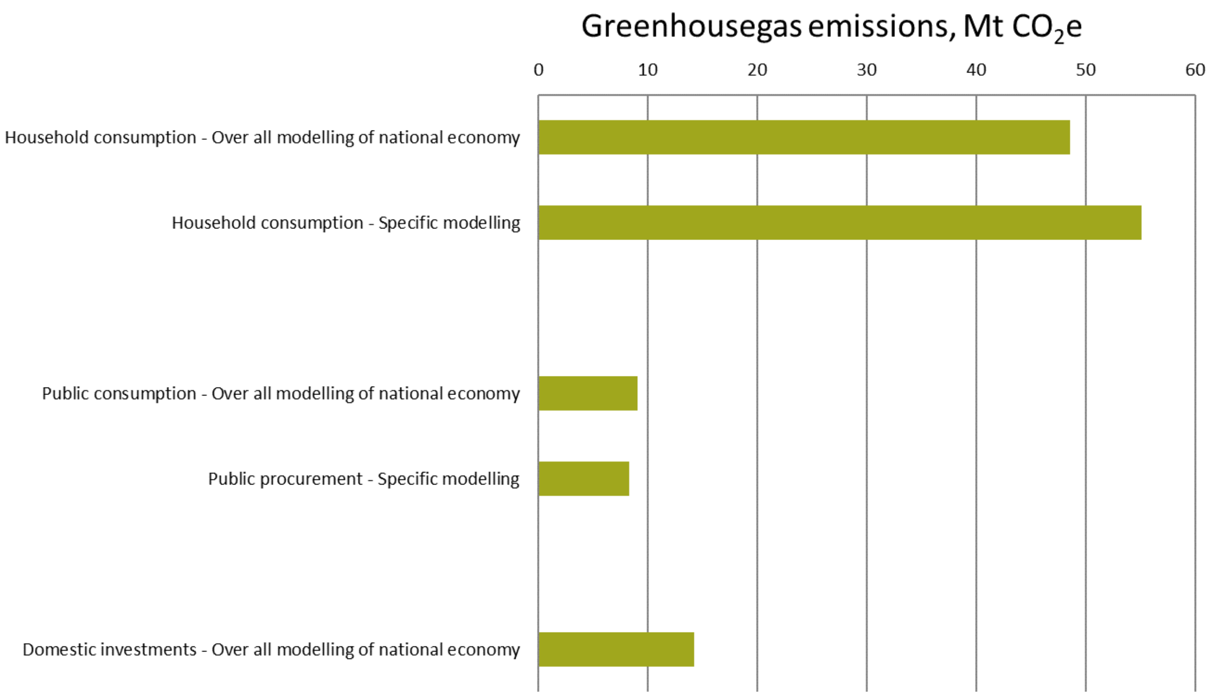

Figure 21. Carbon footprint of consumption and investments estimated with different procedures and data in 2015. Footprint of investments have been estimated only with the over all modelling of the national economy.

It is interesting to compare the situation with Sweden. Table 16 indicates that the share of public consumption in Swedish consumption-based emissions is the same, 12%, as in Finland. The share of household consumption is slightly lower than in Finland, and the share of investments is several percentage points higher than in Finland. The annual emissions calculated per person differ greatly: in Finland, emissions caused by consumption are almost three tonnes (and 28%) higher than in Sweden. However, the difference between emissions caused by consumption is smaller than that between regional emissions, where the difference is 4.5 tonnes per person per year, i.e. the emissions in Finland are 82% higher than in Sweden.

Table 16. Consumption-based and territorial GHG emissions in Finland and Sweden (Steinbach et al. 2018, Naturvårdsverket & Statistiska centralbyrån 2018). Territorial emissions present the official emissions of a country. Note that Finnish consumption-based emissions exclude emissions from non-profit entities serving households and change of stocks (altogether 2%).

	Consumption-based greenhouse gas emissions of the country					Territorial GHG emissions	
	Household consumption	Public consumption	Investments	Total	Per capita	Total	Per capita
	Mt CO_2e per year	Mt CO_2e per year	Mt CO_2e per year	Mt CO_2e per year	t CO_2e per cap. per year	Mt CO_2e per year	t CO_2e per cap. per year
Finland 2015	48.6 (66%)	9.1 (12%)	14.2 (19%)	73.4 (100 %)	13.4	55.2	10.1
Sweden 2014	64 (63%)	12 (12%)	26 (25%)	102 (100%)	10.5	53.8	5.6

Greenhouse gas emissions from the national economy are on the same level as in 2005, though territorial emissions have decreased

Although the principles of the ENVIMAT model have remained the same, the model differs greatly from the calculation used to produce the previous ENVIMAT results for 2002 and 2005 (Seppälä et al. 2009). The aggregation of industries changed, and the calculation of emissions has changed in the GHG inventory. The material flow method has changed completely, and the difference in calculation is particularly significant for the amounts of natural resources and raw materials (i.e. TMR and RMR). If a reliable comparison was to be made with 2005, the calculation should be done again for those years using the current model. Despite this, below we will make some comparisons with the results on the 2005 GHG emissions.

In the light of these figures, there would have been no change in the total emissions of the Finnish national economy in ten years. While the total emissions of the Finnish national economy were 124 Mt CO_2e (Seppälä et al. 2009 p. 86) in 2005, they were estimated at 126 Mt CO_2e in 2015 (Figure 2) in this study. However, the share of final domestic use would have increased by two percentage points, from 56% to 58% (73.4 Mt). Similarly, export emissions would have decreased by two percentage points. Keeping total emissions on the same level gives a different image of Finland's GHG emissions than official statistics, i.e. Finland's territorial emissions, which in 2005 were 69.9 Mt CO_2e and in 2015, 55.2 Mt CO_2e (Statistics Finland 2019b), which was a decrease of 21% in ten years.

The material flows of the Finnish economy are at an unsustainable level

The material flows of the Finnish economy are large from the perspective of both production and consumption. With regard to indicators of material consumption (e.g. DMC, RMC or TMC), Finland is at the top of the material intensity per population numbers in international comparisons (see e.g. Eurostat 2019 and Tukker et al. 2016). In order to satisfy household consumption, significant use of raw materials is caused by the production chains of construction, energy and food. Large material flows in earthworks are emphasised in public procurement. As mentioned in Chapter 3.1, 'gravel and crushed aggregate' is the largest category of materials used in the Finnish economy.

Research literature contains several estimates of the sustainable consumption of natural resources. Bringezu (2015) estimates that a sustainable consumption of natural resources (TMC) would be 8–14 tonnes per person per year and 3–6 tonnes of raw materials (RMC). Lettenmeier et al. (2014), on the other hand, propose 8 tonnes as a sustainable material footprint for the consumption of Finnish households. According to the results of the ENVIMAT model, the use of natural resources and raw materials is currently clearly at an unsustainable level in Finland (TMC 52 tonnes per person per year and RMC 29 tonnes). The extraction of natural resources causes a variety of environmental load and sustainability problems (Krausmann et al. 2009), which in the case of the Finnish national economy are directed both inside and outside of Finland's borders. Chapter 3.3 stated that there is a strong link between GHG emissions and raw material consumption, at least on the level of the average consumer commodity groups.

Transport, housing and food remain the largest sources of consumption emissions

In 2016, housing, transport and food accounted for more than three quarters of the carbon footprint, which is in line with numerous other studies as well as with Finnish consumption (Nissinen et al. 2007, Salo et al. 2016, Seppälä et al. 2009 and Seppälä et al. 2011) and with consumption in other EU countries (Ivanova et al. 2016, Tukker & Jansen 2006). However, the share of housing has decreased and that of other goods and services has increased from the level of 2000.

Following the breakdown used in Sweden, where restaurant services are part of food, and package travel is part of transport (and not part of other goods and services as in the COICOP classification), housing, transport and food accounted for 82% of emissions in Finland and Sweden in 2016 (Table 17). However, the total amount of emissions in Finland is much higher (71%) than in Sweden, and the same applies to each consumption expenditure group. The difference is particularly significant in housing, where Finland's emissions are 173% higher than in Sweden. In Sweden, the relatively small housing emissions are explained by features such as an energy production which is lower-emission than in Finland, and the heat pump technology introduced decades ago, i.e. the use of geothermic and air source heat pumps for heating dwellings.

Table 17. Carbon footprint of household consumption by commodity groups in Finland and Sweden (Naturvårdsverket & Statistiska centralbyrån 2018).

	Finland (commodities grouped as in Swedish data)		Sweden	
Commodity groups	**GHG per capita**	**Share**	**GHG per capita**	**Share**
	kg CO_2e	%	kg CO_2e	%
Food	2 435	22%	1 993	31%
Housing and energy	3 132	29%	1 146	18%
Transport	3 415	31%	2 134	33%
Other goods and services	1 953	18%	1 119	18%
Total	10 935	100%	6 391	100 %

Increase in household consumption eats away the benefits of technological development – guidance is needed

Technological developments, which have been taken into account in the calculations of this study, particularly for domestic products, have reduced greenhouse gas emissions from household consumption. The decarbonisation of heat and electricity production will affect the carbon footprint of households both directly and indirectly. In addition, the electrification of society will reduce combustion emissions.

However, during the period examined, this was not sufficient to cover the increase in emissions resulting from increased consumption. The change in the consumption structure has reduced emissions only slightly.

While technological changes have been encouraging, the pace of change should accelerate so that the increase in consumption expenditure would not eat away the emission reductions achieved by technological means. Consumption may be steered towards a more sustainable and lower-emission consumption structure, and changing the relative prices of different consumer goods, for example through taxes, affects the structure of consumption and the selection of low-emission products in each product group. For example, many services cause less emissions per euro spent than other consumption does.

There is currently no effective price mechanism in the effort sharing sector that would steer towards lower-emission consumption in the same way as price control at its best works in the emissions trading sector. The important role of imports in terms of emissions means that more information should be obtained on the carbon footprints of products and that it should be possible to use this information – both for the selections made by consumers and companies and for the development of social steering methods.

4.2 Opportunities for developing the ENVIMAT model

The ENVIMAT model may be developed in a more detailed direction

The ENVIMAT model may be used to assess greenhouse gas emissions and raw material use caused by both production and consumption activities. In this study, the model and the load coefficients it produces have mainly been used to analyse the life cycle emissions and raw material flows from public procurement and household consumption. The main result is an idea of the magnitude and distribution of the load caused by commodity groups, procurement expenditure groups and investments. The products used in the calculation and their emissions represent the emissions of the average representative products and product groups on the Finnish market. Due to the available input data, the accuracy of the model is not sufficient to examine different products within groups of goods or services. For instance, it is not currently possible to compare different 'environmentally friendly' products to 'ordinary' products using the model. In addition, the knowledge base for imported products should be reinforced. The information currently available on the life cycle greenhouse gas emissions and use of resources caused by imported products is quite crude. Where possible, the data should be further specified by country of import, for example by means of MRIO models. In Sweden, MRIO models have been introduced in the determination of consumption-based emissions (Naturvårdsverket & Statistiska centralbyrån 2018, Steinbach et al. 2018).

The ENVIMAT model may be further developed in the analysis of consumption-based emissions, in terms of both public procurement and household consumption. By studying life cycle emissions from public individual consumption expenditure (i.e. services provided by the public sector to individuals, such as health care, education and social services), it is possible to clarify the view of the carbon footprint of households. In this case, we can refer to the carbon footprint of real household consumption, which also includes the greenhouse gas emissions from publicly funded services for households.

The calculation of emissions from housing should be further developed so that emissions can be more accurately allocated to people living in different types of homes and areas. In the current method of calculating input-output analysis, the high price of housing also increases the emissions from housing. On the overall level, for example, when examining all households in Finland, the results describe the situation, but the examination method is not suitable for examining different types of housing and different areas in its current form. In fact, methods that complement the input-output analysis should be developed for housing.

The ENVIMAT model also provides information on procurement in individual municipalities

The method of analysing public procurement highlighted the totality of GHG emissions from public sector procurement, which proved to be very significant. When investments were taken into account, the magnitude of the emissions was almost 20% of Finland's official or regional emissions. The method also highlighted the importance of different actors and product groups for GHG emissions and raw material consumption.

The breakdown capacity of the method can be improved with reasonable effort so that it can be utilised in the calculation of the carbon footprint of procurement by individual municipalities, associations of municipalities and central government agencies. The method also requires further development in the calculation of combustion emissions from the public sector and for allocating ENVIMAT products to public procurement.

4.3 Conclusions

Finland's consumption-based emissions, i.e. emissions from domestic final use, have not decreased in the same way as the regional emissions or emissions in the official greenhouse gas inventory.

The majority of consumption-based emissions are generated as emissions from household consumption. However, the share of investments and public procurement of the emissions is also significant.

Income level plays an important role in determining the emissions of household consumption, while the place of residence and family type are less important. However, when interpreting this result, it must be taken into account that the method used cannot distinguish the variability of product carbon footprints in each commodity group.

In addition to the development of domestic energy production and other manufacturing processes towards decreasing emissions, the reduction of consumption-based emissions requires guiding of households, municipalities and associations of municipalities as well as state organisations to select goods and services with a low carbon footprint.

The national economy's environmentally extended input-output method ENVIMAT provides a methodological framework that can be developed further, for instance, by improving the accuracy of import product data by means of regional input-output tables (MRIO) and by developing municipal and organisation-specific emission calculations.

GLOSSARY

am	association of municipalities
Carbon footprint	Life cycle greenhouse gas emissions of goods or services, taking into account the life cycle from the consumption of natural resources to the manufacture of different materials and components, the production, distribution and trade of the end product or service, the consumption phase, and the recycling and waste phase. The ISO 14067 standard deals with the carbon footprint. In terms of public procurement, the carbon footprint is not exactly as defined for all product groups: for instance, the waste management phase is missing.
CO_2e, CO_2-eq	Carbon dioxide equivalent, unit for greenhouse gas emissions
COICOP	Classification of Individual Consumption According to Purpose
Commodity	Products, goods or services intended for the needs of consumers
DMC	The direct material consumption is derived by deducing the amount of exported material from the direct material input.
DMI	The direct material input consists of the amount of material extracted from Finnish nature and the direct amount of imported material.
Emission intensity	Also emission coefficient, life cycle emission of the product or service or load per monetary unit
Emissions	Used as a synonym for greenhouse gas emissions in this report, as the report does not address other emissions.
Greenhouse gas emissions	For the purposes of this report, the greenhouse gas emissions for each product group and organisation include carbon dioxide, methane, nitrous oxide and F gas emissions.
- **GHG**	- Greenhouse gases
- **GHG emissions**	- Greenhouse gas emissions
HBS	Household Budget Survey
Intermediate product	Product used for manufacturing products in other branches of activity
LCI Data Bank	A database service for data used in life cycle assessments, LCI = life cycle inventory
Mkg	Million kilograms, i.e. one thousand tonnes (= 1 kt)
Mt	Million tonnes, i.e. billion kilograms or one thousand kilotonnes (= 1,000 kt)
NETRA	Government Reporting Service NETRA, www.netra.fi

Other central government units	According to the sector classification used by Statistics Finland, other central government units include off-budget funds, universities and limited liability companies supervised by central government units, which are non-market producers.
Public organisations	This report uses the joint designation of public organisation for central government organisations, municipalities and associations of municipalities.
RMC	Raw material consumption describes how much natural raw materials are needed for the domestic use, consumption and capital formation connected to the products.
RMR	The use of raw materials includes the import of the raw material equivalent and the raw materials extracted from domestic nature.
TMC	The total material consumption of natural resources indicates to what extent the total use of natural resources is directed to domestic end use or consumption and investments.
TMR	The total material requirement is the sum of the used and unused extraction (hidden flows) of natural resources.
Use of raw materials	See RMR.

Appendix 1. Public procurement expenditure categories

Table A1.1. Government expense categories.

Materials, supplies and goods	4000	Low value machinery, furniture and transport equipment
	4001	Office supplies
	4002	Books, magzines and other printed matter
	4003	Food, beverages and tobacco
	4004	Clothing
	4005	Detergents and cleaning supplies
	4006	Fuels and lubricants
	4007	Heating, electricity and water
	4008	Buiding materials
	4009	Other materials, supplies and goods
Rents	4200	Rents of land
	4201	Rents of residential buildings
	4202	Rents of other buildings
	4203	Rents of transport equipment
	4209	Other rents
	4204	Rents of computers
	4205	Rents of other machines and equipment
Purchases of services	4300	Maintenace and repair services of residential buildings
	4301	Maintenance and repair services of non-residential buildings
	4302	Maintenace and repair services on land water structures
	4303	Maintenace and repair services of transport equipment
	4304	Maintenace and repair services of computers
	4305	Maintenace and repair services of other machines and devices
	4309	Other maintenance and repair services
	4310	Construction services of residential buildings
	4311	Construction services of non-residential buildings
	4312	Construction services of land and water structures
	4319	Other construction services
	4320	Printing services
	4321	Advertising and marketing services
	4322	Communication services
	4323	ICT services
	4324	Banking services
	4325	Purcase of ICT services from governmental agencies
	4327	Software as a service
	4328	Purchase of financial and HR services from governmental agencies
	4329	Other office administrative and support services
	4330	Education services
	4331	Occupational health services

	4332	Returns from occupational health
	4333	Recreation services
	4339	Other personnel services
	4340	Cleaning services
	4341	Laundry services
	4342	Landscape maintenance services
	4390	Catering services
	4391	Security services
	4392	Expert and research services
	4393	Other eduction services
	4394	Other health services
	4399	Other external services
Other expenditure	4500	Daily allowances
	4501	Kilometre allowances
	4502	Travel services
	4510	Other compensations
	4520	Patent and license fees
	4521	Software license fees
	4529	Other license fees
	4530	Traffic accident expenses
	4539	Other accident expenses
	4540	Membership fees, domestic
	4541	Membership fees, abroad
	4560	Defence equipment
	4570	Real estate tax
	4579	Other taxes
	4589	Other mandatory fees
	4599	Other expences

Table A1.2. Expenditure categories of municipalities and federations of municipalities.

Materials, supplies and goods	Office and school supplies
	Literature
	Food
	Clothing
	Medicines and medical supplies
	Detergents and cleaning supplies
	Fuels and lubricants
	Heating
	Electricity and gas
	Water
	Equipment
	Building materials
	Other materials

External rents	Rents of buildings and apartments
	Rents of machines and devices
	Rents of land and water areas
	Other rents
Purchase of other services	Office and expert services
	ICT services
	Finance and banking services
	Printing services, announcements
	Postal services
	Insurances
	Cleaning and laundry services
	Construction and maintenance services of buildings and landscape
	Construction and maintenance services of machines, equipment and devices
	Accommodation and catering services
	Travel and transport services
	Social and health services
	Education and cultural services
	Employee leasing
	Share of tax expenses
	Other fees, not elsewhere classified
	Other services

Appendix 2. Greenhouse gas emissions (GHG) and raw material requirement (RMR) per euro consumed in household consumption

In addition, the expenditure is shown.

COICOP class	Commodity group	Exp. million €	GHG kg per €	RMR kg per €
	Weighted average		0.5	0.9
	Median		0.3	0.8
C011a	Plant-based food items	5 946	0.6	1.1
C011b	Animal-based food items	6 117	1.1	1.4
C012	Non-alcoholic beverages	1 275	0.5	0.7
C031	Clothing and clothing materials	3 865	0.3	1.1
C032	Footwear	667	0.2	0.9
C04	Housing	29 796	0.3	1.1
C0451	Electricity	977	1.7	4.8
C051	Furniture and furnishings, carpets and other floor coverings	1 810	0.4	1.0
C052	Household textiles	522	0.7	1.2
C053	Household appliances	907	0.4	1.5
C054	Glassware, tableware and household utensils	439	0.5	1.2
C055	Tools and equipment for house and garden	586	0.7	0.9
C056	Goods and services for routine household maintenance	1 123	0.3	0.3
C061	Medical products, appliances and equipment	1 835	0.2	0.1
C062	Out-patient services	2 158	0.1	0.3
C063	Hospital services	857	0.1	0.4
C0711	Motor cars	2 941	0.2	0.2
C0712	Motorcycles	192	0.1	0.4
C0713	Bicycles	212	0.2	1.7
C072	Operation of personal transport equipment	7 103	1.9	0.8
C07311	Passenger transport by rail	352	0.6	1.3
C07321	Passenger transport by bus and coach	737	0.7	1.2
C07322	Passenger transport by tax	257	0.2	0.9
C0733	Passenger transport by air	482	1.1	0.8
C0734	Passenger transport by sea and inland waterway	293	1.0	0.8
C0735	Other transport services	95	0.6	0.7
C08	Communication	2 515	0.1	0.3
C091	Audio-visual, photographic and information processing equipment	1 474	0.6	1.0
C092	Other major durables for recreation and culture	837	0.4	0.9
C093	Other recreational items and equipment, gardens and pets	2 327	0.4	1.1
C094	Recreational and cultural services	4 089	0.2	0.4
C095	Newspapers, books and stationery	1 409	0.2	0.4
C096	Package holidays	1 257	0.4	0.6
C10	Education	431	0.1	0.2
C111	Catering services	5 533	0.3	0.4

C112	Accommodation services	377	0.4	0.5
C121	Personal care	2 419	0.2	0.5
C123	Personal effects n.e.c.	522	0.3	0.6
C124	Social protection	2 016	0.2	0.2
C125	Insurace	2 226	0.1	0.2
C126	Financial services n.e.c.	2 654	0.2	0.2
C127	Other services	693	0.2	0.9
P33	Tourism expenditure abroad	3 143	0.4	0.6

REFERENCES

Ala-Mantila, S., Ottelin, J., Heinonen, J. & Junnila, S. 2016. To each their own? The greenhouse gas impacts of intra-household sharing in different urban zones. J. Clean. Prod. 135: 356–367. https://doi.org/10.1016/j.jclepro.2016.05.156

Björk, I., Steinbach, N. & Berglund, M. 2018. Metodbeskrivning av beräkning an konsumtionensmiljöpåverkan – växthusgaser. Version 2018-10-24. Statistiska centralbyrån SCB.

Bringezu, S. 2015. Possible Target Corridor for Sustainable Use of Global Material Resources. Resources 4(1): 25–54. https://doi.org/10.3390/resources4010025.

Dietzenbacher, E. & Los, B. 1998. Structural decomposition techniques, sense and sensitivity. Economic Systems Research 10: 307 -323.

Ecoinvent 2017. Ecoinvent database. https://www.ecoinvent.org/ [accessed 15.10.2017].

European Aggregates Association 2017. Estimates of Aggregates Production data 2015. http://www.uepg.eu/statistics/estimates-of-production-data/data-2015 [accessed 15.10.2017]

European Environment Agency 2013. European Union CO2 emissions: different accounting perspectives. EEA Technical report, No 20/2013, Copenhagen.

Eurostat 2017. Material flows and resource productivity. https://ec.europa.eu/eurostat/web/environment/material-flows-and-resource-productivity [accessed 15.10.2017]

Eurostat 2019. Material Flow Accounts. http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_mfa [accessed 1.4.2019]

Finnish Environment Institute 2017a. Air pollutant emissions in Finland 1990–2015 informative inventory report. Part 5. Annexes. https://www.ymparisto.fi/fi-FI/Kartat_ja_tilastot/Ilman_epapuhtauksien_paastot/CLRTAPraportointi [accessed 15.10.2017].

Finnish Environment Institute 2017b. ANNEX 1: National sector emissions: Main pollutants, particulate matter, heavy metals and persistent organic pollutants. FI_2017_Submission_1980_2015_13032017. https://www.ymparisto.fi/fi-FI/Kartat_ja_tilastot/Ilman_epapuhtauksien_paastot/CLRTAPraportointi [accessed 15.10.2017].

Geological Survey of Finland 2017. Metals and Minerals Production. http://en.gtk.fi/informationservices/mineralproduction/ [accessed 15.10.2018].

Gill, B., Moeller, S., 2018. GHG Emissions and the Rural-Urban Divide. A Carbon Footprint Analysis Based on the German Official Income and Expenditure Survey. Ecol. Econ. 145: 160–169. https://doi.org/10.1016/j.ecolecon.2017.09.004.

Girod, B., De Haan, P., 2010. More or Better? A Model for Changes in Household Greenhouse Gas Emissions due to Higher Income. J. Ind. Ecol. 14: 31–49. https://doi.org/10.1111/j.1530-9290.2009.00202.x.

Helminen, V., Nurmio, K., Rehunen, A., Ristimäki, M., Oinonen, K., Tiitu, M., Kotavaara, O., Antikainen, H. & Rusanen, J. 2014. Kaupunki-maaseutu-alueluokitus, Paikkatietoihin perustuvan alueluokituksen muodostamisperiaatteet. Suomen ympäristökeskuksen raportteja 25/2014.

Hoekstra, R. & van den Bergh, J.C. 2002. Structural Decomposition Analysis of Physical Flows in the Economy. Environmental and Resource Economics 23: 357.

Ivanova, D., Vita, G., Steen-Olsen, K., Stadler, K., Melo, P.C., Wood, R. & Hertwich, E.G. 2017. Mapping the carbon footprint of EU regions. Environ. Res. Lett. 12: 054013. https://doi.org/10.1088/1748-9326/aa6da9

Krausmann, F., Gingrich, S., Eisenmenger, N., Erb, K.-H., Haberl, H. & Fischer-Kowalski, M. 2009. Growth in global materials use, GDP and population during the 20th century. Ecological Economics 68(10):2696-2705.

Lettenmeier, M., Liedtke, C. & Rohn, H. 2014. Eight Tons of Material Footprint—Suggestion for a Resource Cap for Household Consumption in Finland. Resources. 3(3): 488–515. doi:10.3390/resources3030488.

Lith, P., 2014. Suurten kuntien hankinnat - Tilastollinen muistio yksityisten tavara- ja palveluostojen merkityksestä suurissa kaupungeissa. Lith Consulting Group. Kauppakamari. Ladattavissa: http://helsinki.chamber.fi/media/filer_public/8e/49/8e49a6a0-4166-4951-ac8f-7be410a71eaa/suurten_kuntien_hankinnat_2014.pdf [accessed 12.7.2017]

Luonnonvarakeskus 2017. Luken tilastopalvelut. https://stat.luke.fi/ [accessed 15.10.2017]

Miller, R. & Blair, P. 2009. Input-output analysis, Foundations and extensions. Second edition, Cambridge.

Minx, J., Baiocchi, G., Wiedmann, T., Barrett, J., Creutzig, F., Feng, K., Förster, M., Pichler, P.-P., Weisz, H., Hubacek, K., 2013. Carbon footprints of cities and other human settlements in the UK. Environ. Res. Lett. 8, 035039. https://doi.org/10.1088/1748-9326/8/3/035039

Mäenpää, I., Heikkinen, M., Piñero, P., Mattila, T., Koskela, S. & Kivinen, M. 2017a. MFAfin – Finnish material flow accounts. Method description. Oulun yliopisto, Suomen ympäristökeskus & Geologian tutkimuskeskus.

Mäenpää, I., Heikkinen, M., Piñero, P., Mattila, T., Koskela, S. & Kivinen, M. 2017b. MFAfin – Finnish material flow accounts. Main results. Oulun yliopisto, Suomen ympäristökeskus & Geologian tutkimuskeskus.

Naturvårdsverket & Statistiska centralbyrån 2018. Konsumtionsbaserade utsläpp av växthusgaser. http://www.naturvardsverket.se/konsumtionsutslapp [accessed 2.4.2019]

Niemistö, J., Soimakallio, S., Nissinen, A. & Salo, M. 2019 Lentomatkustuksen päästöt – Mistä lentoliikenteen päästöt syntyvät ja miten niitä voidaan vähentää? Suomen ympäristökeskuksen raportteja 2/2019. https://helda.helsinki.fi/handle/10138/292417

Nissinen, A., Grönroos, J., Heiskanen, E., Honkanen, A., Katajajuuri, J.-M., Kurppa. S., Mäkinen, T., Mäenpää, I., Seppälä, J., Timonen, P., Usva, K., Virtanen, Y. & Voutilainen, P. 2007. Developing benchmarks for consumer-oriented LCA-based environmental information on products, services and consumption patterns. Journal of Cleaner Production 15(6): 538-549.

Nissinen, A., Heiskanen, E., Perrels, A., Berghall, E., Liesimaa, V. & Mattinen, M.K. 2015. Combinations of policy instruments to decrease the climate impacts of housing, passenger transport and food in Finland. Journal of Cleaner Production 107: 455–466.

Nurmela, J., 2008. Kulutustutkimus kestävän kulutuksen mittatikkuna. Katsaus kotitalouksien energian kulutuksen ja kierrätyksen taustoihin vuoden 2006 kulutustutkimuksen perusteella. Katsauksia Tulot ja kulutus 4/2008. Tilastokeskus.

Nurmela, J., 2018. Suomalaisten kulutus on samankaltaistunut. Tieto&Trendit. http://www.tilastokeskus.fi/tietotrendit/artikkelit/2018/suomalaisten-kulutus-on-samankaltaistunut/ [accessed 1.4.2019]

Salo, M., Nissinen, A., Mäenpää, I. & Heikkinen, M. 2016. Kulutuksen hiilijalanjäljen seurantaa tarvitaan. Tieto&Trendit – Talous- ja hyvinvointikatsaus 1/2016: 44-50.

Seppälä, J., Mäenpää, I., Koskela, S., Mattila, T., Nissinen, A., Katajajuuri, J–M, Härmä, T., Korhonen, M-R, Saarinen, M. & Virtanen, Y. 2009. Suomen kansantalouden materiaalivirtojen ympäristövaikutusten arviointi ENVIMAT-mallilla. Suomen ympäristö 20/2009, Suomen ympäristökeskus.

Seppälä, J., Mäenpää, I., Koskela, S., Mattila, T., Nissinen, A., Katajajuuri, J-M, Härmä, T., Korhonen, M-R, Saarinen, M. & Virtanen, Y. 2011. An assessment of greenhouse gas emissions and material flows caused by the Finnish economy using the ENVIMAT model. Journal of Cleaner Production 19(16): 1833-1841.

Statistics Finland 2017a. Greenhouse gas emissions in Finland 1990 to 2015. National Inventory Report under the UNFCCC and the Kyoto Protocol Submission to the European Union 15 March 2017. https://www.tilastokeskus.fi/static/media/uploads/tup/khkinv/fin_un_nir_2015_2017-04-15.pdf [accessed 15.10.2018]

Statistics Finland 2017b. CRF 2015. https://stat.fi/tup/khkinv/khkaasut_raportointi.html [accessed 15.10.2018]

Statistics Finland 2019. Greenhouse gas emissions in Finland 1990 to 2017. Draft. National Inventory Report under the UNFCCC and the Kyoto Protocol Submission to the European Union 15 January 2019.

Steinbach, N., Palm, V., Cederberg, C., Finnveden, G., Persson, L., Persson, M., Berglund, M., Björk, I., Fauré, E. & Trimmer, C. 2018. Miljöpåverkan från svensk konsumtion – nya indikatorer för uppföljning. Slutrapport för forskningsprojektet PRINCE. Naturvårdsverket, 2018. http://www.naturvardsverket.se/978-91-620-6842-4 [accessed 2.4.2019]

Suomen ympäristökeskus 2018. Valvonta ja kuormitustietojärjestelmä (VAHTI). http://wwwi5.ymparisto.fi/i5/463e.htm [accessed 15.10.2018]

Tilastokeskus 2008. Toimialaluokitus TOL 2008. Käsikirjoja 4. Helsinki.

Tilastokeskus 2012. Sektoriluokitus 2012. Käsikirjoja 5, Helsinki.

Tilastokeskus 2017a. Kansantalouden tilinpito [verkkojulkaisu]. Helsinki. http://www.stat.fi/til/vtp/index.html [accessed5.9.2017]

Tilastokeskus 2017b. Yksilöllisen kulutuksen käyttötarkoituksen mukainen luokitus COICOP. Helsinki https://www.tilastokeskus.fi/meta/luokitukset/coicop/011-2011/index.html [accessed 5.9.2017]

Tilastokeskus 2017c. Energiatilinpito. Helsinki. https://www.tilastokeskus.fi/til/entp/index.html [accessed 15.10.2017]

Tilastokeskus 2017d. Energia 2017 – taulukkopalvelu. https://pxhopea2.stat.fi/sahkoiset_julkaisut/energia2017/alku.htm [accessed 15.10.2017]

Tilastokeskus 2017e. Polttoaineluokitus 2015. https://www.stat.fi/static/media/uploads/tup/khkinv/edelliset_luokitukset.pdf [accessed 15.10.2017]

Tilastokeskus 2017f. Kuntatalous – muut taloustiedot. Tiedonkeruun sisältö ja ohjeet. http://www.stat.fi/keruu/kuta/index.html [accessed 3.4.2019]

Tilastokeskus, 2018. Kulutustutkimus 2016 Käyttäjän käsikirja (No. 1/2018), Käsikirjoja. Tilastokeskus.

Tilastokeskus 2019a. Käytettävissä olevat rahatulot. www.stat.fi/meta/kas/kaytettavissa_o.html [accessed 3.4.2019]

Tilastokeskus 2019b. Kasvihuonekaasut > Taulukot. https://tilastokeskus.fi/til/khki/tau.html [accessed 3.4.2019]

Tukker, A. & Jansen, B. 2006. Environmental impacts of products. A detailed review of studies. Journal of Industrial Ecology 10 (3): 159-182.

Tukker, A., Bulavskaya, T., Giljum, S., de Koning, A., Lutter, S., Simas, M., Stadler, K. & Wood, R. 2016. Environmental and resource footprints in a global context: Europe's structural deficit in resource endowments. Global Environmental Change 40: 171–181.

Tulli 2017. ULJAS - Tavaroiden ulkomaankauppatilastot. http://uljas.tulli.fi/ [accessed 15.10.2017]

UNEP 2011. Decoupling natural resource use and environmental impacts from economic growth. A Report of the Working Group on Decoupling to the International Resource Panel. http://wedocs.unep.org/handle/20.500.11822/9816 [accessed 3.4.2019]

Valovirta, V., Alhola, K., Leväsluoto, J., Nissinen, A., Oksanen, J., Pelkonen, A. & Turtonen, A. 2017. Innovatiiviset julkiset hankinnat – määrittely, mahdollisuudet ja mittaaminen. Valtioneuvoston selvitys- ja tutkimustoiminnan julkaisusarja 82/2017.

Valtiokonttori 2015. Liikekirjanpidon tilikartta. http://kasikirja.valtiokonttori.fi/Public/default.aspx?nodeid=17287 [accessed 3.4.2019]

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